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THE RAND/TAC INFORMATION AND ANALYSIS SYSTEM: VOLUME II— THE ANALYSIS PROGRAMS AND PROCEDURES

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PREFACE

The RAND/TAC information and analysis system provides for the collection, processing and analysis of operations, maintenance and supply data, using an IBM 1401 computer to assist in data purification and in the management and evaluation of aircraft operations and support at base level. The system is unique in that the data collected are identified with the specific sortie (and in some instances to the specific leg within the sortie). This allows the user to perform many kinds of analyses not ordinarily possible, relating mission use to reliability, manpower and spares usage.

The system grew out of a number of special field tests (e.g., Rapid Roger, Skoshi Tiger, Tack Down) exploring the feasibility of using a small business computer to assist with materiel and operations problems at base level. In the tests prior to Combat Dragon, it was necessary to "create" the maintenance analysts through an extensive educational process. Combat Dragon was unique in that Air Force personnel carried out the entire project from data collection through final writeup with no assistance from RAND, other than the initial training in the use of the system.

It is now possible to organize the loose collection of notes, procedures and programs into a formal system description. Accordingly, this RAND effort comprises four Memorandums containing essentially the package of materials used in training the Combat Dragon team. The information is organized as follows: Volume I (RM-5666-PR) is for data collectors and editors responsible for providing the data bank to be used in subsequent analyses; Volumes II (RM-5667-PR) and III (RM-5668-PR) are for analysts (especially people who will be doing maintenance analysis) to familiarize them with the available programs and analysis products, and to encourage them to ask questions and explore the data in an imaginative way; and Volume IV (RM-5669-PR) is for the "data services branch" of the evaluation or analysis team, to identify procedures and to impart an understanding of what the analyst is attempting to do.

Surprisingly, even though the system is entirely computerized, readers need not have a knowledge of computer hardware and software to

follow the text. A knowledge of the details of aircraft weapon systems would be useful, for although we describe such operations, the descriptions are somewhat cursory. In particular, a familiarity with aircraft maintenance procedures would be useful.

The concepts, techniques and programs of the RAND/TAC information and analysis system should be adaptable to future Air Force base-level management information systems, whether manual or highly mechanized. Provided that the appropriate computer is available, the RAND/TAC system can easily be introduced at a base and used without modification for field tests or other purposes. Recent changes in a number of standard Air Force forms and in data linkages, however, may make them preferable to the RAND/TAC forms for a particular base exercise.

With modest changes to current Air Force data collection procedures and reprogramming of the analysis packages, the system would provide a valuable supplement to current base analysis reports--a supplement more attuned to questions that are and should be asked by base maintenance management. The system will also provide a detailed guide and check list for the design-development of new base-level information systems and should provide direct input to analysis portions thereof.

SUMMARY

The RAND/TAC information and analysis system provides for the collection, processing and analysis of operations, maintenance and supply data, using a small business computer to assist in data purification and in the management and evaluation of aircraft operations and support at base level. It is unique in that operational and logistics variables are interrelated through several features of the data and analysis systems to permit identification of operational events connected with a particular sortie and relate these to explicit maintenance or supply actions preceding or following the sortie, management actions, and key environmental conditions.

The system consists of a series of forms for collecting operational data, maintenance actions, maintenance manpower availability, aerospace ground equipment utilization, supply demand, cannibalization and issue data, a series of computer programs and manual procedures for editing, reformatting and processing to provide basic displays, and other programs to provide basic analysis packages. The system is designed to minimize duplicative recording of data elements, and has flexible computer programs to permit a wide variety of analyses.

The four volumes constituting this effort present a complete system description, together with instructions on how to perform analyses using the system programs. Volume I (RM-5665-PR) contains the description of and procedures for collecting and editing the data--the forms, procedures and program operating instructions. Volumes II (RM-5667-PR) and III (RM-5668-PR) are concerned with the analysis programs and procedures, and with analysis design and methods. The first emphasizes how the programs work, the second how questions can be answered. In a sense both volumes are written for a career that currently does not exist in the Air Force: the maintenance analog of the operations analyst. A person interested in this field should be versed not only in maintenance but also in data processing, computers, statistical methods and experimental design.

Each time RAND participated in a special field test, such as Combat Dragon, Skoshi Tiger, and Tack Down, it was necessary to "create" the maintenance analysts by an extensive educational process. Volume

II attempts to encapsulate the first part of that educational process. It introduces the prospective analysts to the data bank, the programs and the procedures needed to process the operations, maintenance and supply analysis data.

Volume III is based on the second stage of the learning process. It assumes that the user has now mastered the elements of the program and can focus his attention on answering questions. Thus it addresses analysis fundamentals: dependent and independent variables, data fields, sorting, data selecting and tagging. Then it discusses a variety of areas of interest to maintenance management and shows how each can be explored with the system. Finally, some of the background and philosophy of experimental design is discussed.

Volume IV (RM-5669-PR) describes the computer programs used with the system. To encourage a rapprochement between the analysts and the programmers, we have attempted to include sufficient information for the programmer to understand the general outlines of what the analyst is attempting, as reflected by the functions of the computer programs.

ACKNOWLEDGMENTS

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GLOSSARY

Abort rate	The rate of aborted sorties made by a unit in a given period. The most frequently used equation is the following: abort rate = sorties aborted/sorties attempted.
Action taken	The type of maintenance performed: repaired, removed and replaced, calibrated, etc.
AGE	Aerospace ground equipment.
AGE utilization	A display showing both active and standing flight-line utilization of AGE.
Aircraft display	Also called flight-line display and flight-line queue sort. Shows pictorially the maintenance and status history of each aircraft for a 24-hour period.
Base-line	Such data are counts of the times an event was attempted, e.g., sorties flown in a certain category.
Break-rates	Along with write-ups, break-rates are the major independent variables in determining aircraft recovery and turnaround, and are therefore the major determiners of sortie generation capability. Break-rates are determined for both aircraft and aircraft systems. The equation is as follows: break-rate = system fix count/sorties flown.
Chi-square	An analysis program that makes statistical comparisons of frequency counts to determine whether nonrandom behavior exists.
Code 799	No defect discovered.
Code 800	Removed or replaced to facilitate maintenance.
Code T	Removed for cannibalization.
Code U	Replaced after cannibalization.
Combat Dragon	An exercise with A-37A aircraft in Vietnam.
Cost-effectiveness	An exercise with F-4C aircraft at MacDill Air Force Base.
Daily package	Processing of operations, maintenance, supply and scheduling data by means of edit, error listing, and aircraft and work center displays.
Delay time	The accumulation of work interruptions on each system and each work center, by aircraft.
Demand rates	Most frequently, supply demand rates. Most frequently, demand rate = demand (request)/sorties flown

Deviation-Degradation (DEVDEG) program	A computer program. Lists and counts missions' deviation-degradation data from the 308 forms.
Dichotomous data	Data that has only two categories: for example, yes-no, 0-1, hit-miss, aborted-nonaborted, malfunctioned-nonmalfunctioned.
Easy data	Data collected by one person at a single collection point, as opposed to tough data.
Edit mask card	Locates the decimal phase that is edited into the data field just before printing.
Edit program	Searches for and identifies errors, reformats data, relieves data recorder of all possible unnecessary burden.
Eight/two pocket	Card drop pocket on the 1401.
Eighty-eighty (80-80) listing	Records are printed as they exist on the card (or tape) without separation of the fields.
Error listing	An image of each card containing a computer-detected error plus a description and location of each error.
ETIC	Estimated time to in-commission status.
ETR delay code	Equipment temporarily removed.
Field location card	Locates low- and high-order positions of the fields on the record.
Flight-line display	See aircraft display.
Frequency Counter (FREQ) program	Searches any field of unknown and unsorted data, builds a table, and counts the frequency of entries in the field.
Gang punch	To punch identical or constant information into all of a file of cards.
Gross fix time	Period from touchdown to end of maintenance. Includes unscheduled maintenance only.
Gross turnaround	Period from touchdown to end of maintenance, includes both scheduled and unscheduled maintenance.
Hard data	Keypunched data, as opposed to soft data.
Harmonic mean	The method of computing helps minimize the effect of unequal sample size by using the reciprocal of n.
Hourly Frequency Accumulate	A program that computes the frequency counts for resource utilization for each of the 24 hours during the day.
How malfunction code (how mal)	Describes the nature of the malfunction: burned, distorted, cracked, over'rated, etc.

Independent variables	May affect system behavior, as opposed to dependent variables, which are the things being affected.
KBA	Killed by air.
K-97 report	Deck of maintenance data forwarded to the Logistics Command.
Lag time	Period from touchdown until maintenance begins.
Man-hours	Hours of direct labor.
Manpower Utilization Sequence	Relates personnel utilization (direct on-equipment labor) to sorites flown.

	Manpower utilization	Searches each minute of the hour to find the number of men working each hour.
	Manpower available	Produces a summary card showing the number of men available for each hour of each work center day.
	Touchdown counts	Produces a card for each day showing the number of touchdowns for each hour of that day.

Mission essential items	Essential items for accomplishing the objective of the sortie.
MDC	Maintenance data collection portion of AFM 66-1.
MND	Maintenance nondeliveries.
Net fix time	Active fix time when work is being accomplished. Lags and delays are not included, refers only to unscheduled maintenance.
Net turnaround	Same as net fix time except it includes the scheduled maintenance as well.
NORM	Not operationally ready, maintenance.
NORS	Not operationally ready, supply.
NORS-G	Not operationally ready for supply, grounded.
N/P pocket	Card drop pocket on 1401.
NRTS	Not reparable this station.
Observed frequency	Count of successes, failures, aborts, etc.
Off-equipment file	MDC records of bench repair actions.
On-equipment bench repair	Repair done without item going through conventional materiel control channels.

OR rate	Operationally ready rate: OR rate = hours ready/hours possessed.
Oxnard format	The output format of the Edit program always includes clock hours. Oxnard refers to the project for which the format was designed.
Oxnard project	An exercise with F-101 aircraft at Oxnard Air Force Base.
Pearson product moment correlations	Statistical measure showing the amount of relationship between two measures.
PS code	Primary-secondary code. A column (in record format Ms) for use as a squadron (or other) designator.
Quantitative data	Manhours, elapsed time. Contrasts with frequency count data.
Rapid Roger	An exercise with F-4C aircraft in Thailand.
Recombine program	A special purpose program used in the Recovery Sequence. Eliminates duplications, adds a dummy sortie card to the end of each tail number subset and merges the sortie deck output by Single, First and Last with the nonsortie data output by Compute Elapsed Time.
Recovery Sequence	Preprocessed edit output data. This involves computing elapsed times, converting to Julian Calendar, and coding the sortie data for first, last and single sorties of the day. Requires Col. 80=0, =2, =3 records. Involves four programs: Compute Elapsed Time; Single, First, and Last; Recombine; and Clint.
Recovery Summary (RECSUM) program	An analysis program. Provides a complete, readily comprehensible summary of aircraft recovery and turnaround in a one-page general summary with back-up pages containing detail.
SAC Full Force	An exercise with B-52, B-47, KC-135 and KC-97 aircraft.
Sequential Frequency Distribution	Summarizes and displays events across 24-hour period.
7-cards	Produced by Clint program. Aircraft recovery records that include only the unscheduled maintenance action and the postflights. Aircraft turnaround records that include both scheduled and unscheduled maintenance data.
8-cards	Produced by Clint program. System records that include both scheduled and unscheduled maintenance actions.

9-cards   Produced by Clint program. Work center
                                 records that include the scheduled and
                                 unscheduled maintenance actions of all work
                                 centers.

Sick bird analysis   Determines whether individual tail numbers
                                 show atypical write-up rates based on the
                                 sorties flown, by obtaining the sortie and
                                 write-up counts for each aircraft card, using
                                 Chi-square testing for nonhomogeniety.

Single, First and Last (S/F/L)   A special program used only in the Recovery
   program   Sequence. Makes a single sortie card from
                                 the pairs of sortie cards resulting when a
                                 flight crosses midnight. The program also
                                 determines and tags by tail number the sequence
                                 of sorties flown each day.

Skoshi Tiger   An exercise with F-4C, F-5A, and F-100 aircraft
                                 in Southeast Asia.

Soft data   Data not keypunched, as opposed to hard data.
                                 Generally verbal information.

Sortie length   Measured from takeoff to chock time (engine
                                 shut-down).

Sparrowhawk   An exercise with F-4C, F-5A, and A-4 aircraft
                                 at Eg'in Air Force Base.

Splattergrams   Displays write-ups, sortie-by-sortie, to give a
                                 snapshot history of each aircraft. Program
                                 computes write-up rates for each aircraft and
                                 prints them at the end of each tail number.

Spread-field list   Provides a listing with each field isolated
                                 from the adjacent one by blanks. Much easier
                                 to read than an 80-80 listing.

Support general codes   Scheduled maintenance codes.

Supply 1050 system   The 1050 is the standard supply computer.

System repeat write-up analysis A repeat write-up is identical to the write-up
                                 on the previous sortie.

Tack Down   An exercise with C-130 aircraft at Pope Air
                                 Force Base.

Throughput time   Time it takes to get a job out of the computer,
                                 measured from request to delivery.

Tough data   Data collected by many persons at many points,
                                 tough to get.

TMS   Type, model and series of aircraft.

Turnaround data	Output that includes all maintenance actions.
Units produced	A count of maintenance actions. Each job is assigned one unit of work.
Vector	A record that describes the status of a system at a given time.
When discovered code	Code showing when the malfunction is discovered: before flight, during flight, during inspection, etc.
Work Center Display	Also called work center queue sort. Shows 24-hour pictorial history of work center.
Work unit codes analysis	Summarizes on one page all the meaningful information on form 300 records for each work unit code.
Write-ups	A malfunction is "written-up," i.e., described. Along with break-rates, write-ups are the major independent variables in determining aircraft recovery and turnaround.
Z-score	Score expressed in sigma units.
ZI	Zone of Interior (USA)
Zone punch	11-punch (-) or 12-punch (+) on card used when punching Alpha or special characters.

I. INTRODUCTION

The philosophy behind the design of the analysis programs de-
scribed in this Memorandum involves two closely related maxims that
we follow, as far as possible:

1. Avoid special purpose programs that can process only a
   single data type and produce only a specific product.
   Instead, emphasize general purpose programs; these are
   format free and can be applied to a variety of problems.

2. Use a modular construction. This implies the ability
   to tie together several general purpose programs with
   a series of instructions to the computer operator who
   can then obtain a desired output.

The most common sequence in our analyses consists of four opera-
tions (modules): select, tag, sort, process.

1. Select a subset of the data (e.g., 2-digit system recovery
   data for January and February).

2. Tag the data (e.g., separate the pre-modification from
   the post-modification records, and identify "tag" both
   groups).

3. Sort (e.g., majoring on 2-digit syste code and minoring
   on tagged codes).

4. Process (e.g., compute an analysis of variance for each
   system to determine the impact of the modification on
   recovery time).

These four general purpose modules are preferable to one special
program. Although a general purpose program could be written, since
it is easy to visualize a program using the four modules as subrou-
tines, we feel it is easier and often quicker to use the computer
operator as the "master program." This attitude about modular design
is adopted principally because the development of new modules expands
the capacity for analysis, whereas the development of a master control
program only adds a degree of elegance to the existing capacity.

The philosophy is not without cost. It puts a much greater de-
mand on the user who must

a. know what is in the data;

b. know what the programs can do with the data;

c. be able to visualize the compatible combination of a and
b .hat will yield the information he desires;

d. be able to provide the machine operator with the proce-
dures necessary to link the program modules together
to achieve meaningful output.

Because much analysis is a kind of creative exploration, it is
desirable that the analyst, the programmer, and the machine operator
work together much more closely than is traditional. Often the pro-
cedures are developed by mutual discussion; hence, comptroller person-
nel play an active role in obtaining the end products. The most re-
sponsive system, of course, is one where the analyst functions as his
own programmer and machine operator. Such a system is practically
obtained only by synergic behavior.

It is to the creative user that we direct our Memorandum. At
best, since most of his creative ability will come only with experi-
ence, we hope to assist him through the first trials. To help develop
the facility sketched above (particularly item c), we have included
several possible uses for each general purpose program. To follow the
subsequent exposition the user will not need to know programming, but
he will require some data processing vocabulary--field, record, file,
alpha, alpha-numeric, gang-punching, and sorting by majors and minors--
as indicated in the example of a data file shown in Fig. 1.

SEX	GRADE	WEIGHT	
BOY	7TH	120	8
BOY	7TH	123	8
BOY	8TH	127	8
BOY	8TH	121	8
BOY	8TH	129	8
GRL	7TH	110	8
GRL	7TH	111	8
GRL	8TH	114	8
GRL	8TH	117	8

Fig. 1--A 9-record data file

A data file consisting of nine records is shown. Each record
(a punched card in this instance) contains four fields: the sex,

grade, and weight of each individual, plus a gang-punched "8". The records are sorted first by grade, putting the 7's in front of the 8's. Then they are sorted by sex (i.e., major on sex and minor on grades also expressed, sorted by grade within sex). The entries in the sex field are alpha; grade, alpha-numeric; weight, numeric.

II. THE ANALYSIS PACKAGE

The analysis package has two major divisions: the recovery
sequence that summarizes data by sortie, and the analysis programs
that process the data from the recovery sequence and the editing
sequence.

RECOVERY SEQUENCE

Before processing with the Clint program, which summarizes data
by sortie, the recovery sequence must preprocess the edit output data
(see Vol. I). This involves computing the elapsed times, converting
to Julian Calendar, and coding the sortie data for first, last, and
single sorties of the day. The recovery sequence uses the edit out-
put tape of tail-number display data sorted by time within tail-
number sequence.

Major	Col.	79	AN	PS code
	Cols.	35-38	N	tail number
	Cols.	11-12	N	month
	Cols.	9-10	N	day
	Cols.	13-16	N	hour-minute
	Col.	80	AN	card code
Minor	Cols.	73-78	AN	report number

Because the recovery sequence requires only the Col. 80-0, -2
and -3 records (the maintenance, sortie and status records), the in-
put can be restricted to reduce the processing time. The special
CET output tape T1 is used for this purpose. The sequence involves
four programs used in the following order:

1. Compute Elapsed Time (CET) adds the elapsed time and Julian
   day to each record, and splits the data into two groups--
   the sortie records and all other data.

2. Single, First, and Last (S/F/L) combines the two records
   that result from sorties flown across midnight, and makes
   the first, last, and single sorties of the day determina-
   tions for each aircraft.

3. Recombine merges the sortie data output from step 2 with
   the non-sortie data output from step 1. Recombine also
   eliminates duplicate records and adds a dummy sortie record
   (that the Clint program may require) at the end of each tail-
   number subset.

4. Clint summarizes the data by sortie.

These four programs are described in detail below.

Compute Elapsed Time (CET)

The Compute Elapsed Time program is a general purpose program
that computes the elapsed times of edited data (Oxnard formats des-
cribed in Volume I), and converts the Gregorian start time to the
Julian dates that Clint requires. Some formats, like the comments
and sortie deviations, for example, do not include stop times; when
the computer senses such cards, it omits the elapsed time computations.
CET can also be used as a general purpose record selector. It may be
used to select and punch all the data of a given card type by punch-
ing the desired card code from Col. 80 of the data record into Col. 3
of the program control card (format C13). If tape input is used,
punch the tape count in Cols. 1-2. See Fig. 2 for the CET program
setup. Recovery sequence processing requires sorting in the flight-
line display sequence.

For general processing control, switch action is as follows:

Switches I/O and A are always "on".

Switch B--"on" for card input.
          "off" for no tape output.

Switch C--"on" for tape output (on unit 2).
          "off" for no tape output.

Switch D--"on" to punch only the card format selected by the
          input control card.
          "off" to punch all cards

Switch F--"on" to eliminate sortie cards from output. This
          special setting is used for the recovery sequence;
          the sortie cards are punched, processed, and re-
          combined with the data. This setting provides a
          sortie free file to combine with the processed
          sortie cards.
          "off", all output is written on the output tape.

Switches G and E--Not used.

When CET is used as a part of the recovery sequence, the follow-
ing procedures are used.
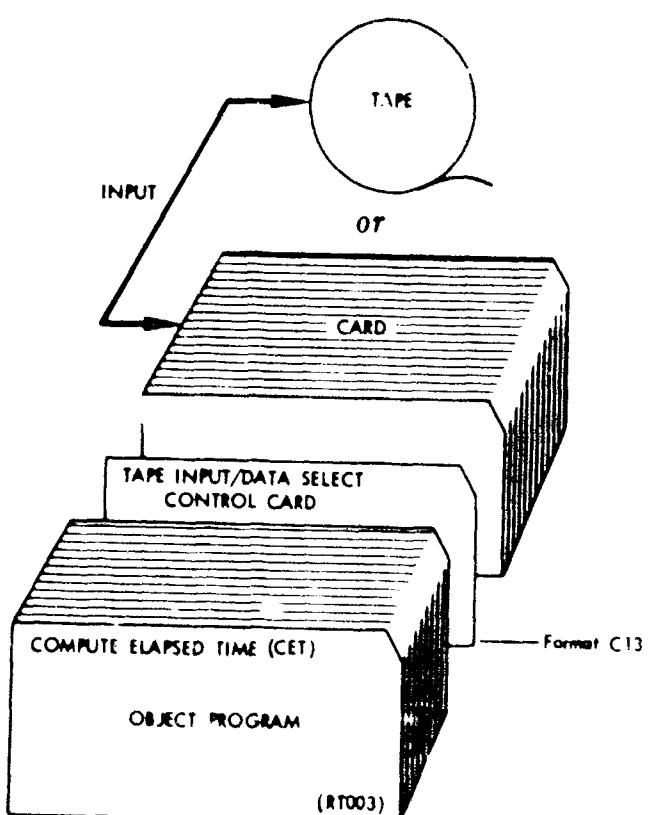
Fig. 2 -- Compute elapsed time program setup

Punch a numeric "2" in Col. 3 of the control card (format C13) to obtai sortie card punch-out.

Switch B--"on" for card input.
"off" for tape input (tail number display tape).
The input tape must be mounted on unit 1.

Switch C--"on" to write output on unit 2, and Switch F "on" to eliminate the sortie cards from the output on unit 2.

Switch D--"on" to indicate that only selected cards (i.e., numeric "2" in Col. 80) are being punched.

The tape on unit 2, tape T1, is saved for processing with Recombine, and the deck of sortie cards is processed by Single, First and Last.

Single, First and Last (S/F/L)

S/F/L i a special purpose program used only in the recovery sequence. It makes a single sortie card from the pairs of sortie cards resulting when a flight crosses midnight. Takeoff time is

taken from the first card of the pair, the touchdown from the second, and the elapsed time is recomputed. The program also determines and tags by tail number the sequence of sorties flown each day. Single sorties are tagged "S", the last sorties of the day are tagged "L". All others are tagged "F" for first. Sortie data must be sorted in the tail number display sequence. Figure 3 shows the S/F/L program setup.

Switches I/O and A are set "on". No other switches are used.

Recombine

Recombine is a special purpose program used only in the recovery sequence. It eliminates duplications, adds a dummy sortie card to the end of each tail-number subset (the Clint program may need this), and merges the sortie deck output by S/F/L with the non-sortie data output by CET. Recombine has two inputs--the sortie data processed by S/F/L and the sortie-free data output by CET, i.e. tape T1. Figure 4 shows the Recombine program setup.

Switches I/O and A are set "on".

Switches B through F--not used.

Switch G--"off" prints duplicate records eliminated from file. "on" eliminates printing.

CET's output tape, tape T1, is mounted on unit 1, and a scratch tape is mounted on unit 2. The object program is followed by a control card (format C9) containing the number of input tapes. The output tape from Recombine, called the T2 tape, is used as input to the Clint program.

Clint[*]

Except where necessary, the following discussion addresses Clint as a single program, although it was necessary to split the original

[*] The program is named for Clint Smith who uses it extensively in SAMSON, a maintenance-operations model. See T. C. Smith, G. D. Brown, P. A. Mason, R. Moulenbelt, and H. J. Shukiar, A User's Manual for SAMSON II: The Support Availability Multi-System Operations Model, The RAND Corporation, RM-4923-PR, November 1967; and G. D. Brown, R. Moulenbelt, and H. J. Shukiar, A Programmer's Guide to SAMSON II, The RAND Corporation, RM-5235-PR, November 1967.
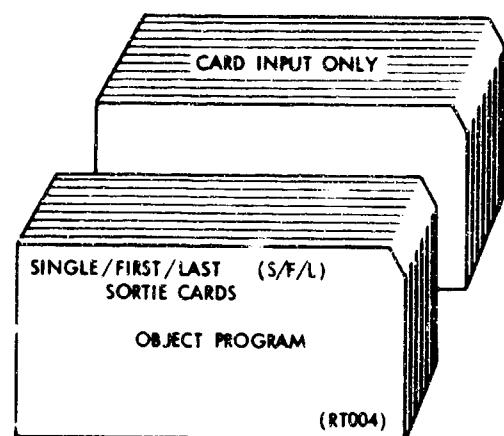
Fig. 3 -- S/F/L sortie cards program setup
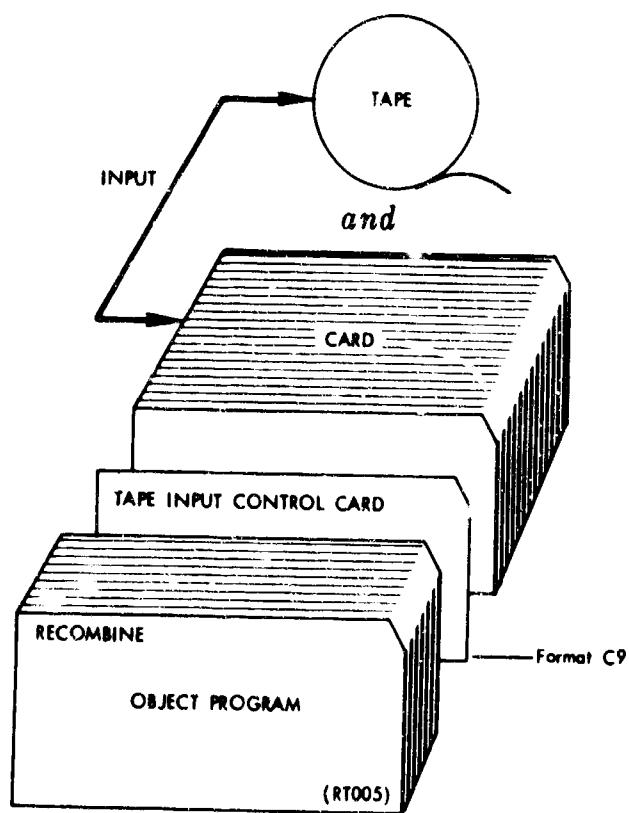
Fig. 4 -- Recombine program setup

7044 package into two separate programs for the 1401. One program
computes the aircraft and system summaries, the other computes the
work-center summaries. Clint summarizes data by sortie, and provides
inputs for most of the analyses. For this reason, it is the most
important program in the analytical package. Accordingly, it is de-
scribed in much greater detail than the others.

Early in our efforts to develop computerized methods for analyz-
ing maintenance data, it became evident that we could make more mean-
ingful analyses by relating all information to the specific sortie.
The greatest advantage of gathering data by sortie is that it provides
two measures: the means (aborts, recovery times, break-rates, write-
up rates, etc.) and the variances (the distributions of the scores
around the means). Only by having both is it possible to make def-
inite statements such as "write-up rates have significantly increased
this month."[*] The variance data enable us to test various write-up
rates and determine whether a true difference exists among them.

Data that can be gathered by the sortie fall into four major
categories:

1. Operational data. Who flew where on what kind of mission
   with what kind of success?

2. Sortie (debrief) data. What tail number flew or aborted
   at what time and what equipment malfunctions occurred?

3. Maintenance data. What resources were required (and for
   how long) to recover the aircraft from the effects of the
   sortie? Status, off-equipment and cannibalization data
   are also included.

4. Supply data. What parts were provided or backordered to
   make the recovery?

Currently, Clint only combines item 2 and the on-equipment portions
of item 3. This combination provides most of the data necessary to
determine the day-by-day functioning of the flight-line. (Volume III
describes the technique for combining all four data elements.)

The sortie summary of the aircraft is computed by dividing the
aircraft into a number of individual black boxes whose repair is

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[*] A. Sweetland, Some Statistical Methods for Maintenance
Analysis, The RAND Corporation, RM-4443-PR, April 1966.

ordered in time. This is seen in the simplified display of Fig. 5.
The program sweeps through the data (ordered by time within tail num-
ber sequence) as illustrated. As the program encounters each new
sortie record, it outputs the summarized data of the previous sortie,
and begins summarizing the data of the next sortie.

The computer keeps three kinds of records.

1. The aircraft record. This includes the lag until work first
    starts, the length of the work, and the length of any work
    interruptions (delays). Records are kept of a considerable
    amount of associated information: Man-hours, units. sortie
    length, sortie type, etc. These are defined below.

2. The systems record. A similar accounting is kept for each
    of the aircraft's major systems. Since it is desirable to
    vary this list of systems from time to time, control is
    provided through the use of system tables (format M3). The
    computer processes only data identified in the tables. For
    example, the user may not be interested in maintenance done
    under support general system codes, so he eliminates the
    codes from the tables.

3. The work center record. This keeps a record of each work
    center's actions, and is identical to the system record.
    Similarly, it is controlled by reading in a table of work
    centers (format M1).

The aircraft record is always produced even if no action occurs. To
minimize data volume, however, the system and work center records are
output only when a maintenance action occurs. Had the data of Fig. 5
been processed, the result would have been one aircraft record sum-
marizing the complete recovery, one system record for the flight-
control system, and two work center records, one for the hydraulic
shop and one for the electrical shop.

Clint output (formats R1, R2 and R3) contains two types of data--
quantitative (e.g., man-hours) and categorical (e.g., sortie types).
The quantitative elements are described first. All times are given
in hours and tenths of hours.

1. Lag time (Cols. 28-32). This is measured from touchdown.
    For the aircraft record, lag time ends when maintenance
    begins. System and work center lags end when work begins
    on each specific system or by each specific work center.
    In Fig. 5, lag time for the hydraulic shop begins at 1200
    and ends at 1500 when that shop first begins work. Lag
    for the electrical shop ends at 1300, as do the lags for
    the aircraft and the flight-control system.

```
12   13   14   15   16   17   SORTIE   SYSTEM   SHOP

F F F F                                FCF

      2 2 2 2                                     FLTCTL   ELECT

            2 2 2 2                               FLTCTL   HYDRL

            FFF   FCF
```

Fig. 5 -- Functional check flight of an aircraft

(A functional check flight (FCF) touches down at 1200 hours. After a
lag lasting until 1300 hours, a two-man team from the electrical shop
works for an hour on the flight-control system. This is followed by
a delay until 1500. The hydraulic shop then works for an hour on the
same system. The aircraft then repeats the check flight.)

2. Delay time (Cols. 33-37). These are accumulations of
    work interruptions on each system and on each work center.
    Recording is kept by aircraft (no work on any system is
    being accomplished).

3. Net fix time (Cols. 38-42). This is the active ! x time
    when a maintenance data collection (MDC) record indicates
    work is being accomplished.

4. Gross fix time (Cols. 43-47). For the aircraft record,
    this is the time measured from touchdown to the end of
    maintenance. By definition, gross fix time for the
    aircraft record is the sum of lags, delays and net fix
    times. For system and work center records, however,
    gross fix time excludes lags.

5. Units produced (Cols. 58-60). These are defined by AFM
    66-1. The measure is essentially a count of maintenance
    actions. Each job having a definite beginning and end
    (e.g., each repair job, each TOC, each bench check) is
    assigned 1 unit of work.

6. Man-hours (Cols. 61-65). This accumulates man-hours
    consumed in direct labor.

7. Sortie length, also referred to as flying hours (Cols.
    66-68). This is measured from takeoff to chock-time
    (engine shut-off) whenever possible, r   in from
    takeoff to touchdown. Life begins at chock-time in
    the world of maintenance.

The following categorical items always appear on the records. When used as major or minors (i.e., independent variables), they allow the user to compare information thus far discovered to effect aircraft recovery and turnaround.

1. PS code (Col. 1). Primary-secondary code. Most frequently this is used to separate data by aircraft type or squadron, but it has also been used to separate flights. This entry is controlled by the tail-number table used in the edit program and is a local option.

2. Card code (Col. 2). The aircraft (sortie) record is coded 7; the system 8; and the work center 9. These records are referred to as the 7-, 8-, and 9-cards.

3. Tail-number (Cols. 03-06).

4. Date (Cols. 7-15). Year, month, day, hour and minute. Note that the field defined by Cols. 1-15 is in the most frequently used sorting sequence.

5. Take-off time conversion code (Col. 16). Depending on the time constants in the program, take-off time may be recoded as "A", "B", or "C" work shift--morning, afternoon or night, etc. We are currently using "D" for day (0530-1730 hours) and "N" for night.

6. Sortie configuration, also called sortie type, contains the type of sortie flown (Cols. 17-19). Combat and firing range codes generally describe the type, numbers, and locations of ordnance carried.

7. P and H code (Col. 20). The program senses the MDC data for the type of maintenance. If the code indicates that a periodic, phased, or hourly inspection has taken place, a "P" or "H" is shown. Because these inspections may take several days, it is often desirable to exclude them for analyses concerned with immediate turnaround capability.

8. SFL code (Col. 21). This code indicates whether the sortie was the single, first, or last sortie of the day for the tail number appearing in Cols. 3-6. This code, particularly when combined with the take-off time code, allows the user to determine how scheduling affects recovery and turnaround. Since scheduling affects recovery and turnaround more than any other variable, the reader is encouraged to explore this effect. See RECSUM section for suggestions.

9. NORS-G code (Col. 22). If a NORS-G (Not Operationally Ready for Supply, Grounded) status card is sensed, the data are tagged with a "G". It is often desirable to exclude these data when computing turnaround capability.

10. ASW code (Cols. 23-27). Entries here differ by card type.
    The aircraft record (Col. 2=7) is blank in this field and
    can be used for special identification. The system records
    (Col. 2=8) contain the 2-digit work unit code (Cols. 23-24
    only); the work center records (Col. 2=9) contain the work
    center in Cols. 23-27.

11. Identification (Cols. 69-80). Twelve characters are pro-
    vided for run identification. It is particularly desirable
    to use this when several different kinds of runs are made
    from the same data.

The coding that appears in Cols. 17-19 (load configuration) is
not a fixed requirement. Any desired identification may be used,
depending on local needs: special exercises, flight crews, call
signs, unique missions, mission success-failure, released-nonreleased-
impounded aircraft, combat damage, and so on. These can all be made
part of the permanent record by minor changes in local coding require-
ments. Although 3 characters seem like a limited number, using 24
alpha and 10 numeric provides for 40,000 combinations (3^{34} power).

Several special features of Clint are described below. Mainte-
nance preceding the first sortie and following the last sortie that
each aircraft flies is excluded from the summaries; it is generally
not known whether these represent complete sets of data. Most peace-
time flying schedules, however, are completed before the end of the
month, and the aircraft are recovered immediately. The data for this
last recovery can be retrieved by using the dummy sortie records that
Recombine provides. Switch action on Clint controls the use of the
dummy sortie records.

Occasionally, the user wishes to omit data containing atypically
long recovery times. For example, an aircraft may stand in NORS-G
for several days before recovery can be completed. Such atypical data
can be eliminated by using the lag and delay constants entered on the
control card (format C1). Lag and delay times are compared with these
constants; when the constants are exceeded, the record is not produced.
The reader is urged to try using the constants of 999.9 hours (circa
6 weeks), select the long gross recoveries, and consult the flight-
line displays to see what is happening. We discourage using small
constants until the analyst is familiar with maintenance practices.

When Clint is output on tape, the aircraft record (Col. 2-7) also gives a complete recap of system break-rates. Beginning in Col. 94 of the tape record, the program builds a table corresponding to the table of system codes used; for instance, Col. 94=system 11, 95=system 12, etc. If the system requires maintenance, a numeric "1" is entered; if not, the column is left blank. The count of the "1's" (called total write-ups) is recorded in Cols. 131-132. The aircraft break code is in Col. 130, so that if any system requires maintenance, record "1", otherwise "Blank".

The concepts of write-ups and break-rates are only meaningful when applied to unscheduled maintenance.* Our procedure has been to include system codes 11-97 plus the postflight (system 03200) to obtain a complete recovery picture. Then, when computing break-rates and write-up rates, the postflight actions are deleted by the switch settings provided by both RECSUM and the Analysis of Variance programs described below. Control of write-up computation is also provided by the input table construction, as described below.

When aircraft status records are included, the program will summarize the NORM (not operationally ready, maintenance) and NORS-G entries. These data are useful when exploring the problem of inflated gross fix times, but we discourage their use unless the information is needed by sortie, which is rarely the case. Provision is made to get a complete status analysis, as described in the section on Analysis of Variance.

The following suggestions and comments are intended to help the user during the frustrating time when he is making his first learning runs.

The most important thing to remember is that processing and output are controlled by the tables of work centers (format M1) and work-unit codes (format M3). Data that do not match both tables are not processed, see below. Hence, when the tables do not include all the work centers and work-unit codes contained in the input data, the 7-, 8-, and 9-card man-hour and unit summaries will not agree unless

---

*Unscheduled maintenance is also referred to as recovery time, get well time and time to OR. Output that includes all maintenance actions (systems 01-97) is called turnaround data.

identical tables are used. During exploratory phases we suggest using the Frequency Count program (described later) to get these tables. Later, since this produces an awesome number of records, the reader will wish to become more discriminating. To do this, he will need to know the following program sequencing.

The program first senses for a legal work center code; that is, the work center on the record exists in the work center tables. Having found a legal code, the computer next tests for a legal system code. Then it does the necessary calculations and bookkeeping for both the work center and system codes, and updates the summary for the aircraft record. Note that only when a legal work center and system code is found, will there be an updating of the aircraft record. This sequence can be used to limit output by excluding the unwanted work center or system from the tables.

The table of 2-digit system codes also controls the break-rate and write-up records appearing in Cols. 94-132 of the aircraft records. Only systems punched "1" in Col. 3 of the system tables are included in the output. By convention, this is unscheduled maintenance (system codes 11000-97000, plus postflight actions, system code 03200). This output can be generated by switch action control.

Occasionally, it is necessary to explore the support general codes beyond the 2-digit level. This is accomplished by recoding the data. Assume one wishes to explore the uploading sequence. The various system codes on the input records can be recoded: UM for up-load, munitions; UT for upload tanks, pylons; UI for upload inspec-tions and checks; and so on. These recoded data are combined with the sortie records and processed by Clint. The system tables must also include the special codes. When this information is processed, it generates a summary of the uploading sequence.

The MDC, sortie, and status data that Clint uses must have been processed in the recovery sequence described using programs, CET, S/F/L and Recombine. Data must be sorted by time within tail-number sequence.

A control card (format C1) containing the lag and delay constants and run identification is required. We suggest punching 9's in Cols.
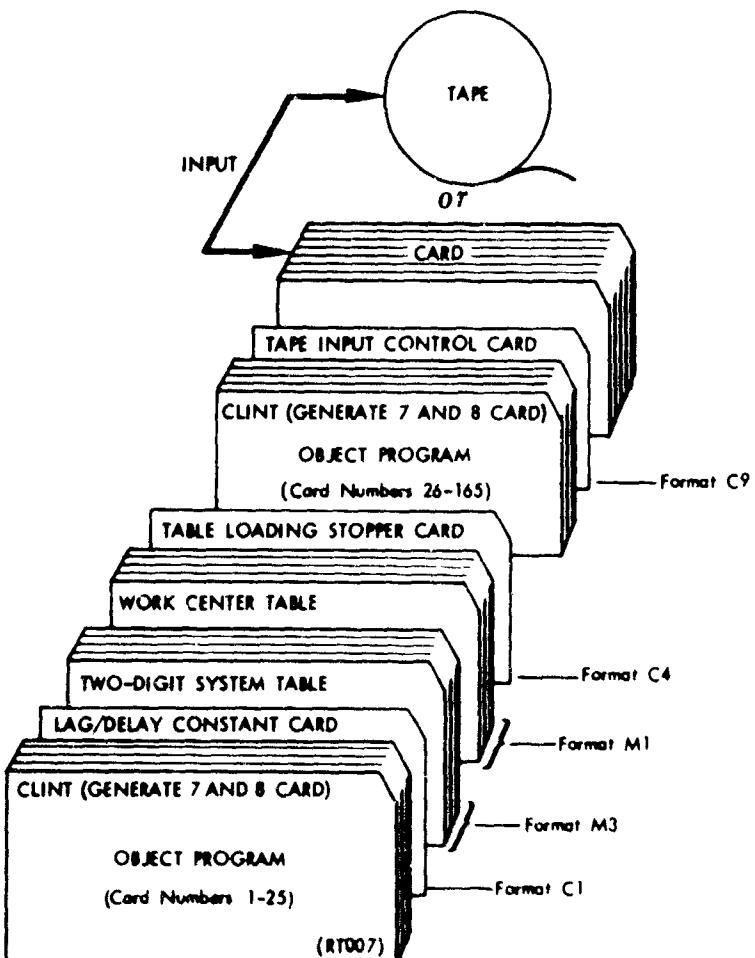
Fig. 6 -- Clint (generate 7 and 8 card) program setup

1-8 of this card as a standard procedure. The tables of systems
(format M3) and work centers (format M1) must be inserted between
cards 17 and 18 of the Clint object deck since a program overlay is
necessary. Columns 72-75 of the object deck identify card series.
The tables must be sorted in ascending sequence by system or work
center, and must contain no duplicate records. The tables are fol-
lowed by a table loader stopper card (format C4) containing an 11-4-8
punch in Col. 80. A control card (format C9) containing the count of
the number of input tapes is placed behind the object deck. See Figs.
6 and 7.

Clint requires the following switch actions:
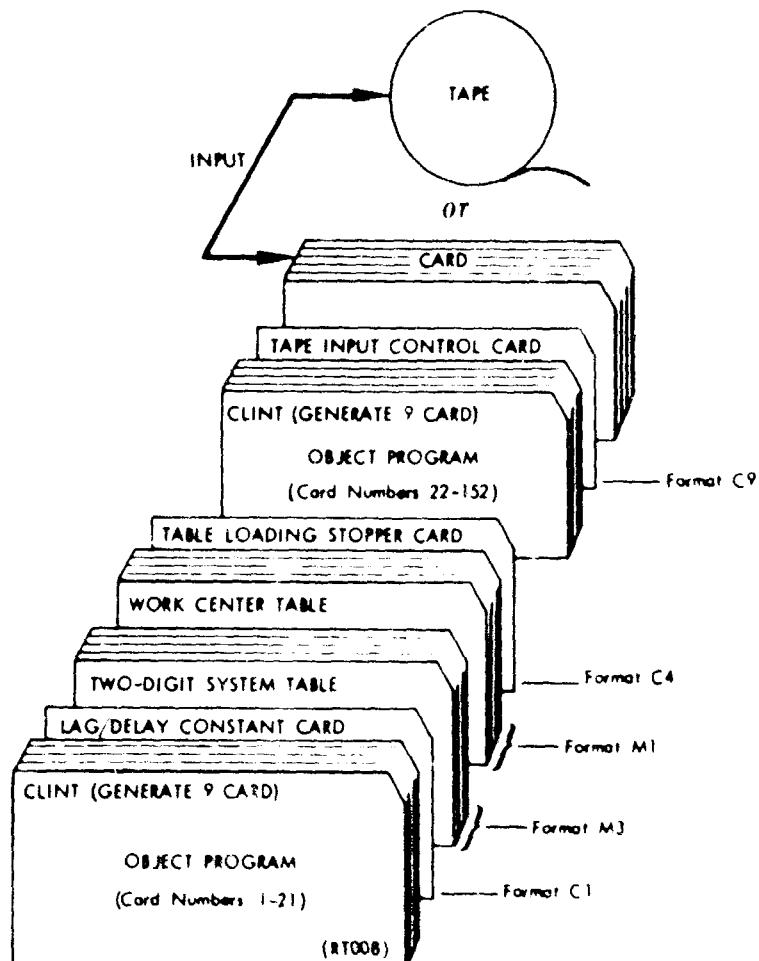
Fig. 7 -- Clint (generate 9 card) program setup

Switches I/O and A are always "on".

Switch B--"on" card input.
"off" tape input (tape T2 on unit 1).

Switch C--"on" to include all systems in the input table when
computing the various data elements.
"off", the support general codes are tested and only
03200 is used in the computations. That is, switch
C "off" produces the recovery data.

Switch D--"on" for card output.
"off" for tape output (tape on units 2 and 3).

Switch E--"on" to use the dummy sortie record produced by
Recombine.
"off", the dummy sortie record is skipped, thus
eliminating maintenance following the last sortie.

The input tape is mounted on unit 1. Tape units 2 and 3 are used to write output. The sortie records appear on tape unit 3 (format R1); the system record or work center records (formats R2 or R3), depending on which program is used, appear on tape unit 2.

THE ANALYSIS PROGRAMS

Recovery Summary (RECSUM)

Most of our program development efforts have dealt with special exercises. A major concern has been how to determine what happened as quickly as possible: an exercise is, literally, an exercise with unknowns. The Recovery Summary program (RECSUM) attempts to deal with this problem by providing a complete, readily comprehensible summary of aircraft recovery and turnaround in a one-page general summary with back-up pages containing detail, as illustrated in Figs. 8 and 9.

RECSUM is a special purpose program in that it accepts only Clint output. The program first produces a one-page pictorial and numerical summary for each selected minor, followed by a one-page total data summary for the major. The majors and minors are the analyst's option. For example, he can obtain a summary of the 7-card recovery data for each tail number plus a summary for the entire squadron by minoring on the tail number (Cols. 3-6) and majoring on the PS code (Col. 1). Using the 8 cards, the analyst can obtain a summary for each system by minoring on Cols. 23-24 (system code) and majoring on the card code. He can also select the data field he is most interested in--net or gross recovery. The computer then gives him a detailed pictorial and numerical summary of this field, plus a gross summary of all other data fields.

The details of the RECSUM output (see Fig. 9) are the following:

1. Major and minor fields. These entries are the locations of the record as indicated in the control card (format C3) and show the low- and high-order positions of the fields.

2. Titles. The analyst selects these. In general, the title (format C10) should define the major and the data sample. The two subtitle cards (format C11) should describe the mnemonic codes appearing in the matrix.

Fig. 8 -- Aircraft turn round time distribution

MAJOR-- 7 COLS 2- 2   SAMPLE AIRCRAFT TURNAROUND TIME DISTRIBUTION - S/F/L

SINGLE, LAST AND ALL OTHER SORTIES   SORTIE TYPE

AVG-- 8.01   SIGMA-- 10.62   N-- 464   STDERR-- .49   VARIANCE-- 112.88   TOTAL-- 3716.8
TOTAL SORTIES 480   16 SORTIES REQUIRED NO FIX TIME   BREAK-RATE-- 97/100---.967
TOTAL MANHOURS-- 11509.6   SATURATION INDEX-- 3.1   AVG T/A ALL SORTIES--- 7.74

84 ITEMS GREATER THAN 12 HOURS,
OUT OF ROUNDS DATA ARE COMPUTED BUT NOT PLOTTED

FILE TOTALS

	LAG	DELAY	NET	GROSS	UNITS	MANHOURS	FLY-HRS	WRITE-UPS	BREAKS	MORS	NORM
TOTALS--	159.2	2193.6	3716.8	6069.4	8079	11508.6	661.0	1126	334	6247.3	2519.5
AVG--	.34	4.73	8.01	13.08	19.14	24.80	1.38	2.43	.72	13.46	5.43

Fig. 9 -- Aircraft turnaround time distribution

3. Ordinates. These are column counters.

4. Hours and P. This shows the percentage of the sample terminating by a certain hour; for example, 7 percent of the jobs or recoveries are completed by one hour, 35 percent by two hours, and so on. These percentages do not include the zero duration data.

5. Average, sigma, N and other conventional statistical computations. This line includes only the nonzero data.

6. Total sorties. A better term would be total records in the sample. This entry includes the zero-duration data, followed by the number of zero-duration records. Break-rate is calculated by dividing the nonzero records by the total record count.

7. Saturation index. This should be viewed with caution when sample size is less than thirty. It is computed by dividing the total man-hours by the total net fix time to yield the average team size when active maintenance is being accomplished.

8. Average turnaround for all sorties. This computation includes the zero-duration records. It is obtained by dividing "Total" (shown on the right) by the record count.

9. Lags, delays and similar terms. These are defined in the discussion of Clint.

This program has frequently been used to explore the effects of daily flying schedules on aircraft recovery. In this instance the minor is Col. 21 of the sortie cards that contain the S/F/L information. As a general statement the F sorties indicate average maintenance time when it is known the aircraft will fly again that day. Comparing F and L sorties gives a picture of how much deferred maintenance is taking place. The S sorties show the behavior when recovery is done without pressure. The major field is generally the PS code (Col. 1).

RECSUM also writes (on tape unit 2) a record of the summaries at each break in the minor (see format Y). This can be used to obtain summary data from all the 7-, 8-, and 9-cards by sorting on the appropriate entry. For example, a summary for each tail number within the squadron could be obtained by majoring on the squadron (Col. 1) and minoring on the tail number (Cols. 3-6). Similarly, a summary for each day could be obtained by minoring on the day (Cols. 10-11).
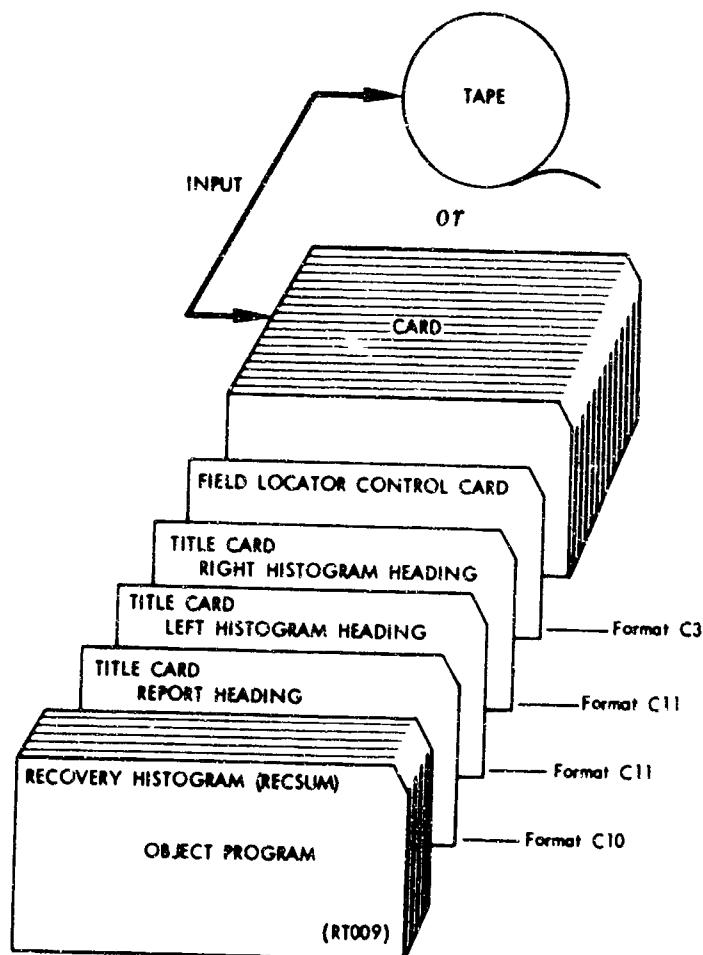
Fig. 10 -- Recovery histogram (RECSUM) program setup

When using RECSUM, data must be sorted by major and minor. Four control cards are required, as shown in Fig. 10.

1. A general title card (format C10).

2. A heading (title) for the left-hand histogram (format C11).

3. A heading for the right-hand histogram (format C11). Note that the histogram entries may be any of the single-digit codes appearing on the data cards: squadron, aircraft type, sortie types, load configuration, shift.

4. The field control card (format C3). Note that numeric "4" is always punched in Cols. 1, 4, 7, 10, 13, 16 and 19, and numeric "2" is always punched in Col. 22. Field 13-15 of the control card identifies the location of the character that will appear in the left-hand histogram (S/F/L). Field 16-18 identifies the location of the right-hand character (sortie type).

Field 19-21 defines the beginning of the data field on Clint output that the program is to treat in detail. Field 22-24 defines the location of the asterisks that tag the item being detailed. The relationship between these two fields is fixed and only the following pairs are legal.

Desired Item Detail	Cols. 19-21 are Punched	Cols. 22-24 must be Punched
Lag	432	215
Delay	437	225
Net recovery	442	235
Gross recovery	447	245
Units	460	255
Man-hours	465	265
Sortie length	468	275
Write-ups	532	285
Breaks	530	295
NORS	452	304
NORM	457	315

Col. 80 of the field control card must have an 11-3-8 punch. Either card or tape(s) input may be used.

Switches I/O and A are always set "on".

Switch B--"on" for card input.
        "off" for tape input (tape on unit 1).

Switches C and D--not used.

Switches E, F and G--"on" eliminate, respectively, FCF data,
        hourly and periodic data, and postflight data
        (work unit code 03200).

Samples using the same title and control cards may be stacked.

When Clint is output on tape, and the Col. 2-7 is used for input to RECSUM, the aircraft write-up and break rate summary will appear on the output.

Because of the large amount of information provided and the many ways of sorting Clint output, it is impossible to make any complete description of what can be gained by using the RECSUM program. As an alternative, we suggest that the reader make three separate test runs. The first, described previously, should use the sortie data (Col. 2-7), majoring on the aircraft type and minoring on the S/F/L codes. The second should use the system cards (Col. 2-8), majoring on the squadron

and minoring on the system codes (Cols. 23-24). The third should use
the work center data (Col. 2-9), majoring on squadron and minoring on
the work centers (Cols. 23-27). If the reader compares the results
of these three runs, he will have a good idea of the kinds of recovery
summaries available, plus an understanding of how to use the program.
Further, if he processes the same data with the Analysis of Variance
program (which only involves changing control cards, since sorting
has been done), he will have made a big stride toward understanding
the very complex problem of analyzing maintenance.

Analysis of Variance

This program computes a one-way analysis of variance.[*] Because
it produces most of the parameters used to define quantitative data,
it has become the most general purpose of the programs. Most fre-
quently the program's input comes from Clint. Its next most common
input comes from the CET program. Input may be either cards or tape,
and samples may be stacked. Since most of the intermediate storage
is on tape instead of core, there is virtually no limit to sample or
subsample size. There is also no limit to the number of samples that
may be stacked.

The program prints the subsample means, n, raw score totals, and
variances, as well as a distribution of the subsamples (grouped in
half-sigma units from the sample means). Subsample means are tagged
with one, two, or three asterisks (0.05, 0.01, and 0.001 levels) in
terms of "statistical distance" from the harmonic mean of the sample.
See Fig. 11. In addition, the program provides a number of special-
ized processings controlled by switch action. Zero data may be ex-
cluded from the computations. A constant such as sorties flown may
be read in for converting data counts to break-rates. Selected data
may be punched out to be used as input to the Chi-square program.

The general usefulness of the Analysis of Variance program is
greatly fac'litated by the equivalent of a "variable read format"

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[*] See Sweetland, ibid., for a discussion of how Analysis of
Variance can be used for analyzing maintenance data.

SAMPLE FREQUENCY DISTRIBUTION

EXERCISE - NET FIX TIME - UNSCHEDULED MAINTENANCE (INCLUDES POSTFL)

	CODE--	MEANS	S	N	TOTALS	VARIANCE
SAMPLE 1--	F	1.260*		755	953.7	.48
SAMPLE 2--	L	2.19*		518	1133.6	4.79
SAMPLE 3--	S	4.660**		59	275.0	38.29
SAMPLE TOTALS		1.77		1332	2362.3	

FREQUENCY COUNTS

Z-- 7.4- 2- 1- .3- C 1.8 2.8 .7 3.9 4.9 6.0 7.0 8.1 9.1 10.1 11.2 12.2 13.3
SIGMA 1.4-

SAMPLE 1-- F 14 509 184 79 19
SAMPLE 2-- L 5 177 224 53 14 18 7 1 5 1 6 1 1 1 1
SAMPLE 3-- S 19 9 7 6 4 1 3 1 2 1 2

SAMPLE TOTALS 19 705 417 49 39 22 8 4 6 3 7 1 3 1
CUMULATIVE PERCENT 1 54 86 92 95 97 98 98 98 99 99 99 99 99
PCT OF BOUNDS DATA BELOW AND/OR 8 ABOVE ARE NOT PLOTTED

ANALYSIS OF VARIANCE

	SUM SQUARE	DF	MEAN SQUARE	F
BETWEEN	777.7273	2	389.8636	102.1068
WITHIN	5061.3672	1329	3.8084	
TOTAL	5839.0945	1331	4.3870	

Fig. ? -- Analysis of variance

(When using this program as a general purpose report generator, ignore the statistical computations, since emphasis is on the means, N's (record counts), and totals. The major sense is shown in the upper right following "Code--"; the minor sense is given along the left margin beside the sample numbers. Under "Frequency Counts" the distribut ns are grouped in half-sigma clusters as indicated by "Z--" showing the Z-scores and corresponding standard deviations, "Sigma". In addition to the conventional statistical computations (variances and F-test), the harmonic mean of the total sample is computed along with its standard error. Sample means lying outside the 5-, 1-, and 0.1-percent bounds are tagged with 1, 2, or 3 asterisks, respectively.)

SAMPLE - WORK CENTER ANALYSIS - NET/SIX
CASD 02 02-02   21-27   10-42

SAMPLE FREQUENCY DISTRIBUTION

CODE-- 9
SWITCHES A-B--------- ON
SORTIES-- 480

Fig. 12 -- Analysis of variance break-rate computation

(If desired, a base-line (sortie count) may be read in providing a break-rate (demand rate for work center data) shown to the right under "Break..". The base-line entry appears just above this following "Sorties--". The other entries are defined in Fig. 11.)

defined by the control card; for example, no fixed field location is required. Data records must, however, be identified by sample (major) and subsample (minor). Further, all data are edited with the decimal to the left of the first low-order position. The program edit assumes that all input data have hours and tenths of hours, yards and tenths, mach and tenths, for example. But whole numbers may be processed without decimal place confusion by punching any legal character in Col. 41 of the control card (format C2).

The program's versatility is constrained only by the user's agility in mentally sorting data into major and minor categories. For example, processing with a major on shop, a minor on action taken, and computing on man-hours will yield, for each shop and each action taken, the mean, totals, count, etc., enumerated. Majoring on shop and minoring on month will yield the beginning of trend evaluation. Majoring on tail number and minoring on write-ups yields the beginning of a sick bird isolation. In the latter, turning switch D "off" will produce a deck of input for the Chi-square program to obtain a more vigorous definition of sick birds.

Aircraft status is a typical summary that the Analysis of Variance program makes possible. Using program CET, select the status data (Col. 80=3) output by the Edit program (format Q). Sort majoring on squadron (Col. 79) and minoring on status code (Col. 26). The elapsed time data are located in Cols. 70-72 (in hours and tenths). The result will be a status summary for each squadron.

In the examples cited, we have ignored the F-test computation which tells us whether true differences exist among the means of the subsamples (i.e. the program has been used only to summarize data). In the following illustrations, the F-test is considered. The dependent variable is implied: man-hours, recovery time, write-up rate, mission success, etc. The program can be used, for example, to determine the effects of the type of mission flown, the type of ordnance carried, the work-shift that accomplished the maintenance, an extensive engineering modification, a procedure revision, and combat flying (compared with ZI flying). In all these comparisons, the F-test is
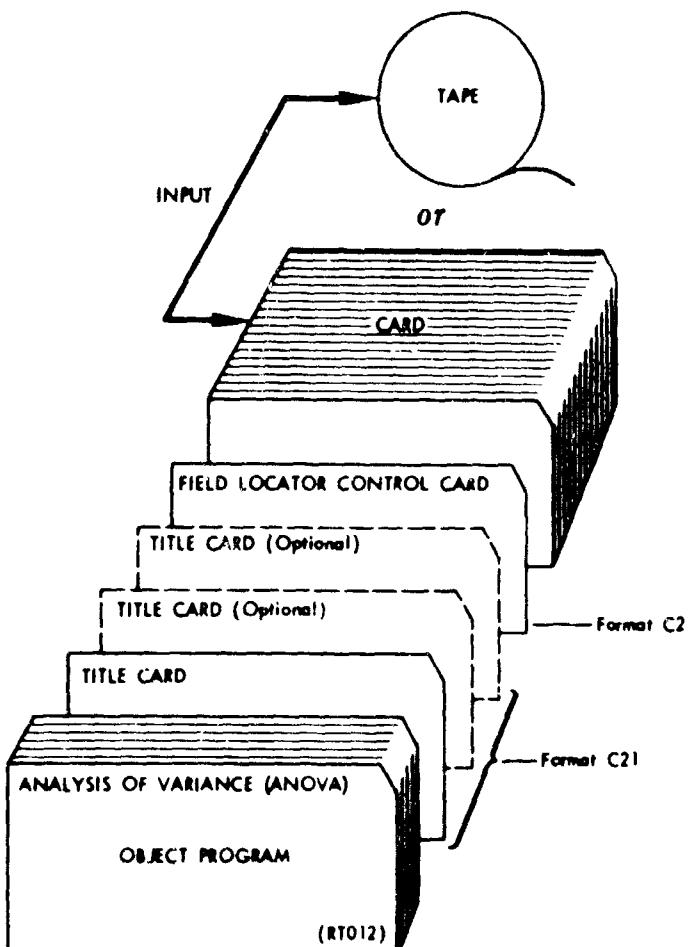
Fig. 13 -- Analysis of variance program setup

scrutinized to determine whether the different conditions are beyond
that expected by normal (random) variation.

Switch action is as follows:

Switches I/O and A are always "on".

Switch B--"on" prints break average
"off" prints break-rate.

Switch C--"on" card input.
"off" tape input (mount input tape on unit 2).

Switch D--"on" eliminates punching
"off" punches inputs to Chi-square (format X).

Switch E--"on" excludes zero data from computations.
"off" includes zero data in computations.

Switch F--not used

Switch G--"on" terminates tape processing (i.e., end of job).
"off" no action.

A scratch (work) tape must be mounted on unit 6 for all processing.

Prior to processing, data must be sorted by major and minor. The program allows printing of three title cards (format C21). Refer to format C2 for punching the field locator control card. A printout of the tape input data can be produced by punching the desired number of pages to be printed in Cols. 6-7 of the control card (format C2). To produce the break average or break-rate computations, the sortie count must be punched in Cols. 1-4 of the control card.

Chi-Square

The Chi-square program is used to make statistical comparisons among frequency data.[*] It computes Chi-square for both dichotomous and non-dichotomous data, and computes an approximated probability (alpha) level as well. To help isolate items causing non-homogeneity of the data, each observed frequency is tested against its expected frequency. If the test indicates an alpha level beyond 0.05, 0.01 or 0.001, it is appropriately tagged. The observed frequency means are averaged to obtain an unweighted grand mean, converted to Z-scores, and plotted as a distribution around the unweighted mean. This distribution is shown to the right of the Chi-square computations in Fig. 14.

Since analyses frequently involve computing a sequence of Chi-squares, the program can process stacked samples. As with Analysis of Variance, a change in the major field indicates a new sample. Unrelated samples, for instance those that differ in format, or those that would not be subsumed under a given title, may be stacked by using new title and control cards. The program senses Col. 80 to determine whether the record is a title card (format C15) or control card (format C16).

The program requires four items.

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[*] See Sweetland, ibid., on the use of Chi-square for analyzing maintenance data.

SPANGDAHLEM AFB F-105 WRITE-UPS PRO-RATED BY SORTIES FLOWN

AIRCRAFT -MAJOR-

BASE-LINE	FO	FT	D2/FT	MEANS	-3	-2	-1	0	1	2	3	4	+5
34	34	43.19	1.96	1.000	.	.	AAR.	.	.	.	.	.	.
27	48	34.30	5.47*	1.778	.	.	.	. ABT	.	.	.	.	.
40	59	50.82	1.32	1.475	.	.	.	C/S	.	.	.	.	.
46	54	58.44	.34	1.174	.	.	CAS.	.	.	.	.	.	.
3	6	3.81	1.26	2.000	.	.	.	.	CHA	.	.	.	.
101	108	128.31	3.22	1.069	.	.	CNV .	.	.	.	.	.	.
3	2	3.81	.86	.667	.	CHK	.	.	.	.	.	.	.
21	15	26.68	5.11*	.714	.	DAY	.	.	.	.	.	.	.
4	3	5.08	.85	.750	.	EVA	.	.	.	.	.	.	.
103	286	130.85	103.96***	2.777	.	.	.	.	.	FCF	.	.	.
6	4	7.62	1.72	.667	.	GAR	.	.	.	.	.	.	.
133	206	168.96	8.12**	1.549	.	.	.	GND	.	.	.	.	.
78	86	99.09	1.71	1.103	.	.	.	NIT.	.	.	.	.	.
63	73	80.04	.67	1.159	.	.	.	NUC.	.	.	.	.	.
2	3	2.54	.08	1.500	.	.	.	TRA	.	.	.	.	.
189	282	240.11	7.31**	1.492	.	.	.	X/C	.	.	.	.	.
752	770	955.34	35.96***	1.024	.	.	.	51-.	.	.	.	.	.

| TOTAL | 1605 | | | | | | | | | | | | |
| | 2039 | | | | | | | | | | | | |

WEIGHTED GRAND MEAN--   1.270
CHI-SQUARE--   250.88

DF--   16

1.288 -UNWEIGHTED-

* THE CHI-SQUARE IS QUESTIONABLE. CHECK FT FOR ENTRIES OF 5.0 OR LESS.

THE PROBABILITY IS BEYOND THE 0.001 LEVEL. THE DISTRIBUTION IS NOT HOMOGENEOUS.

Fig. 14 -- Chi-square

(The major is the upper right code. The minors (general 3-character) are shown in the distributions. The conventional chi-square computations appear under the headings "FO" (observed frequencies), "FT" (theoretical frequencies), "D2/FT" (FO-FT squared and divided by FT), and the means (FO divided by the base-line). One, two, or three asterisks indicate the cell entry was tested and fell beyond the 5-, 1-, or 0.1-percent levels, respectively. Entries in the means columns are converted to Z scores and distributed around the unweighted sample mean in the display on the right.)

1. The base-line. This is used to compute the theoretical
   frequencies. In maintenance analysis, the base-line data
   are a count of the times an event was attempted. Most
   frequently, this is a count of the sorties flown in each
   category oi condition. Other base-line frequencies are
   number of intercepts attempted, number of rounds fired,
   number of target passes, and so on.

2. The observed frequency. This is generally a count of the
   successes or failures. Typical are number of write-ups,
   number of kills, number of dud bombs, number of aborts
   or deviations, number of demands, and so on.

3. The category identification. This is used only to display
   the distributions. It is generally three characters, the
   center character locating the Z-score conversion. The
   categories most frequently used will be tail numbers (last
   three or four digits as may be nec' sary to identify air-
   craft in the analvsis), sortie types and months (for trend
   determination). It is best to pad out one- and two-char-
   acter identifiers to three characters since the center
   character functions as the Z-score locator.

4. The major sense. A change in this field initiates pro-
   cessing of the next sample. Any field that identifies the
   sample may be used. The major identifies the sample in
   the printout, and also sorts the data. The major sense
   is used when one title card is appropriate to several
   samples (see switch C settings). Notice that no minor
   sort is required, although it is frequently helpful to
   pre-sort by category identification. It is also sometimes
   helpful to pre-sort data by base-line (order by frequency
   of exposure) or by observed frequency (order by frequency
   of failure). The distributions of the means resulting
   from these latter two pre-sorts may suggest possible non-
   linear relationships between base-line and the observed
   frequency.

The user will quickly discover that the sample units (n's) pro-
duced by the Analysis of Variance program are often used as observed
frequencies for Chi-square computations. To take advantage of this,
the Analysis of Variance program has a switch action that produces
the Chi-square data input deck; the user, however, must add the base-
line data. The base-line is generally unknown when the analysis of
variance is computed. The following sequence resolves this problem.

Assume the analyst wants to measure the impact the sortie type
has on system ecovery and break-rates. First, using the 2-digit
system recovery file (format R2), he must run the Analysis of
Variance program minoring on sortie type and majoring on system
(Col. 2-8). This will produce the system recovery analyses plus

a deck for the Chi-square computations. Next, using the aircraft re-
covery file (format R1), he must determine the number of sorties flown
for each type of mission, and punch this number into the appropriate
cards of the Chi-square input deck. Processing with Chi-square in this
manner would yield the system break-rates tested for non-homogeneity.

The user must remember that the methods differ for computing
Chi-square from dichotomous (break-rates and demand rates) and from
non-dichotomous data (write-up rates and units produced). The dichot-
omous method always includes computations based on the non-occurrence
frequencies; the non-dichotomous method never includes these computa-
tions.[*] Switch action controls the inclusion of the non-occurrence
computations. Set switch D "off" when computing dichotomous data and
"on" when computing non-dichotomous data.

Since the input data are derived, there is no direct data source
for the Chi-square program. More often than not, the input deck will
result from judicious selection of Analysis of Variance testing. Be-
cause the FREQ program described below is designed specifically to pro-
vide frequency counts of categories, it is ideally suited to provide
inputs to the Chi-square program.

One or more title cards (format C15) may be used. When one
title is used, the computer senses for a change in the major field to
produce a summary. If several titles are used, a separate format
card (format C16) must describe each sample. Thus one can stack sev-
eral related samples behind a general title and control card, or can
also stack separate, nonrelated samples, each having its own title
and control card. See Fig. 15 for the Chi-square program setup

The following switch actions apply:

Switches I/0 and A are always "on".

Switch B--"off" for card.
        "on" for tape input; tape on unit 1.

Switch C--"on" when only one title and control card are used.
        "off" when each sample has its own title and control
        card. When C is "off", data must be sorted by major.

Switch D--"on" when computing nonbinomial data.
        "off" when computing binomial data.

---
[*] Ibid.
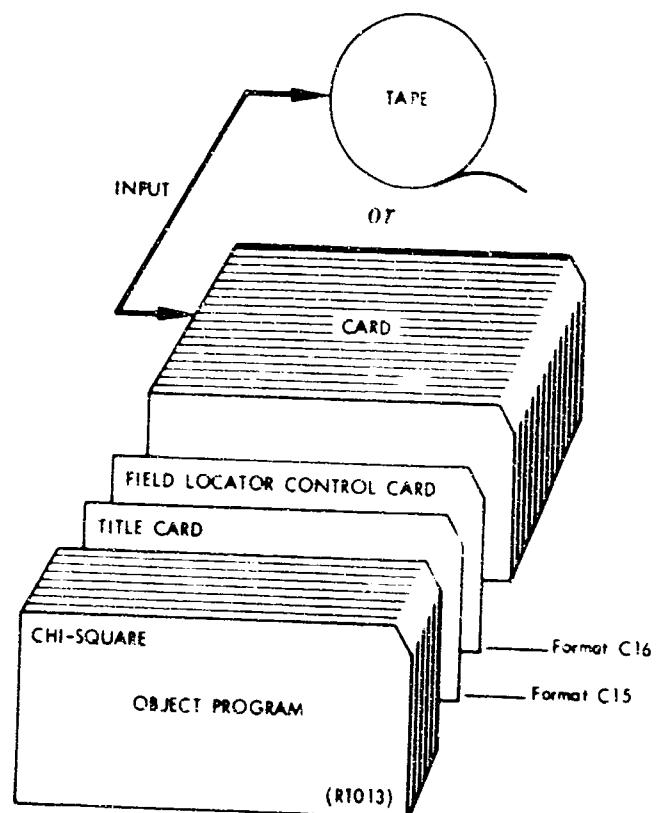
Fig. 15 -- Chi-square program setup

Frequency Counter (FREQ)

The Frequency Counter program (FREQ) searches any field of un-
known and unsorted data, builds a table, and counts the frequency
entries in the field. For example, assume a deck of sortie deviation
data coded by type of deviation: GND-ground abort, AIR-air abort,
BUD-buddy abort, and so on. The program determines not only which
codes occur in the field, but also how frequently they occur, as
shown in Fig. 16. The field may have as many as three separate sub-
fields--major, intermediate and minor--located in separate parts of
the record. The sum of the columns of the three subfields must not
exceed 12. The program starts with a "blank" table. As each record
is read in, the computer asks "Do I have this code in my table?" If
not, it adds the new code.

FREQ is principally used to obtain rapid preliminary estimates
of an unknown phenomenon to serve as a basis for more formal

TWO-DIGIT SYSTEM COUNT -- TAPE T2   DECK   1

FIELD   46- 47

01	3484	.321
03	1211	.111
02	64	.006
04	1394	.128
11	866	.080
74	777	.072
13	504	.046
71	448	.041
91	24	.002
51	99	.009
12	202	.019
42	100	.009
44	76	.007
14	291	.027
06	52	.005
45	252	.023
07	48	.004
73	66	.006
52	141	.013
75	174	.016
09	41	.004
41	139	.013
46	139	.013
23	120	.011
72	33	.003
49	19	.002
77	3	.000
47	47	.004
93	20	.002
05	1	.000
72	21	.002
61	2	.000
96	1	.000
08	1	.000
69	1	.000

RECORDS -   10861

Fig. 16 -- Output sample of FREQ

(The low- and high-order positions of the field being searched are shown to the
right of the word "FIELD". The field entries discovered by the program are given
in the left-hand column and the corresponding record counts in the middle. Total
record count is given to the right of "RECORDS".)

exploration. In this instance, the end-sample (asterisk) card can be quite useful in establishing tentative samples, e.g., first week, second week, third week, and so on. The program is also used to obtain observed frequencies for Chi-square computations. Other uses are to obtain the following: the tables used by Clint (2-digit system and work center), counts of sortie deviations, bench check actions, types of sorties flown, and how-mal actions. Since most maintenance data are nonquantitative (categorical), there is no shortage of opportunities to use the program.

Either card or tape input may be used. If desired, the program will generate a deck of cards (format Z) containing the code (Cols. 13 to 27) and the frequency of occurrence (Cols. 8 to 12), with one code per card. This deck, reformatted, may be used as an input table to the programs requiring it--the Error Edit and Clint.

In using FREQ, it is unnecessary to sort input data. In fact, one main reason for writing this program is to avoid the need for sorting. Frequency counts of sorted data may be obtained by using analysis of variance.

Any number of samples may be stacked if card input is used, but only if the same field is to be searched in all samples. The samples must be separated by a card containing an 11-4-8 punch in Col. 1 (format C19). All samples should be titled by punching the appropriate descriptions in Cols. 19-79 of the control card (format C14).

The following switch actions apply:

Switches I/O and A are always "on".

Switch B--"on" for tape input; mount tape on unit 1.
"off" for card input.

Switch C--"on" to punch a deck of table entries with associated frequencies.

Switch E--"on" if a specific card code (Col. 80) is to be selected.

Switch G--"on" when last input tape has been processed.

The remaining switches are always "off".

The control card locates the field or fields to be counted. The high-order position of the major is punched in Cols. 1-3, the low-order
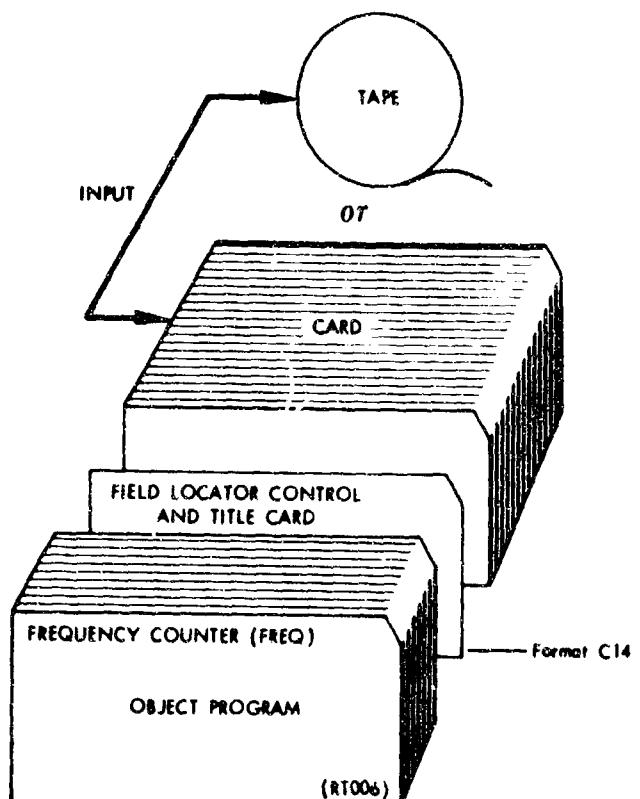
Fig. 17 -- Frequency counter program setup

position in Cols. 4-6. The corresponding positions of the inter-
mediate are punched in Cols. 7-9 and 10-12, respectively. The minor
positions are punched in Cols. 13-15 and 16-18. The field positions
must be preceded with zeros; blanks are unacceptable. If a specific
card type coded in Col. 80 is to be selected from a sample of mixed
formats, punch the desired card code in Col. 80 of the control card.
Columns 19-79 of the control card may be used as a title.

Correlation Matrix

The Correlation Matrix program handles a maximum of twelve vari-
ables, producing a matrix of Pearson Product-Moment correlations. The
program keeps count of data greater than zero and produces two sets of
means and standard deviations: one based on all of the records, and
the other based only on data greater than zero. These two sets show

how missing data distort the correlations by calculating only on xy
pairs greater than zero.

Although there is no limit to sample size, we discourage the use
of samples greater than 500. When sample sizes exceed this, it is
better to break them into two or more random groups, and cross-
validate the results.

By switch option the program also provides a test for question-
able "dependent" variable prediction by tagging those intercorrela-
tions of independent variables that are greater than the correlations
with the dependent variable. All twelve variables may be designated
as "dependent."

The Correlation Matrix program requires a number of control cards
as shown in Fig. 18.

1. Title card (format C18). This must have a 0-3-8 punch in
    Col. 1. The remaining columns may be used as a title.

2. Field designation cards (format C17). Up to twelve are
    used. These locate the left- and right-hand boundaries
    of the fields. One card is used for each variable.
    Columns 1-2 contain the variable numbers 1 through 12
    preceded by zeros. Column 3 is left blank. Columns 4-9
    (6 digits) are used as titles for each field. These
    titles are preferably right-adjusted if fewer than six
    characters. Column 10 is left blank. Columns 11-13
    locate the left-hand (high-order) position of the field.
    Columns 14-16 locate the right-hand (low-order) position
    of the field. Precede with zeros.

    All data are assumed rounded to one decimal place (e.g.,
    hours and tenths, angles and tenths). When processing
    whole numbers, circumvent this by punching any entry in
    Col. 18 of the field definition cards; for example,
    "SHIFT LEFT ONE POSITION". The program then shifts the
    data one position to the left before processing.

3. A card with an 11-4-8 punch in Col. 1 (format C19)
    terminates the loading of the field definition table.

4. If the test for questionable independent variables is
    included, use a card with a 3-8 punch in Col. 1 (format
    C20). In Cols. 2-3, 4-5, 6-7, etc., punch and precede
    with zeros the number of the dependent variables to be
    used; for example, a 03 punched in Cols. 2-3 indicates
    that the data are to be tested against the third variable.
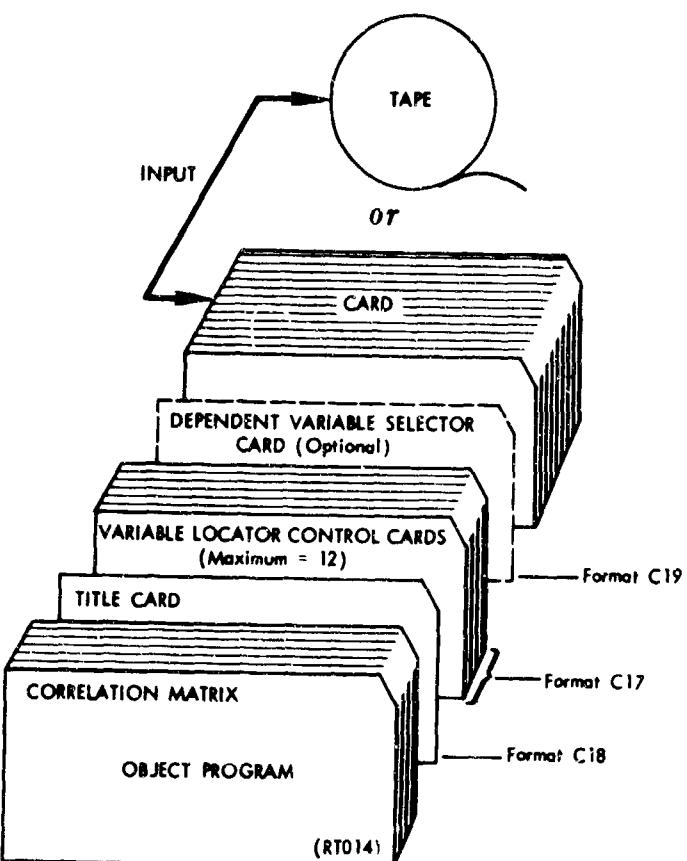
Fig. 18 -- Correlation matrix program setup

The following switch actions apply:

Switches I/O and A are always "on".

Switch B--"on" for card input.

Switch C--"on" for tape input. Tape on unit 1.

Switch E--"on" omits zero (no entry) variables from calculations.

Switch G--"on" omits printout of dependent variable tests.

Deviation-Degradation (DEVDEG)

This is a special purpose program for listing the mission devia-
tion-degradation data from the 308 forms. The only data acceptable
are the form 308 edit outputs (format U).

Using CET, select the edited data by punching "H" in Col. 3 of
the control card. Sort by deviation code.

DEVIATION AND DEGRADATION ANALYSIS

TAIL	DATE	MRRM	W/U/C	SYM	-CALL-	
0838	1201	1840	4154A	AIR	WASP	TE FLAP BARBER POLES AT 310 KNOTS
0839	1801	2110	41500	AIR	MATE	BLC LITE ON TAKE OFF
7687	0109	1110	41000	AIR	NICK42	SMOKE IN COCKPIT
7710	0809	1840	71400	AIR	CHICAG	INS PROB EM/NO SPARE
0735	2010	0900	23000	AIR	KODAK	AUX AIR CONR OPEN
0819	0210	1815	14000	AIR	KNIFE	FLIGHT CONTROL VIBRATIONS
7500	1309	2020	45000	AIR	HUDSON	CENTER LINE TANK DOES NOT FEED
7645	1909	1850	11000	BUD	LOVER	SYMPATHY WITH 7710
7650	3008	2040	11000	BUD	KODAK	SYMPATHY FOR 7687
765C	1509	1940	11000	BUD	ROSCO	SYMPATHY WITH 7687
7641	2508	2035	11000	BUD	MURRIC	SYMPATHY ABORT
7642	1808	0001	11000	BUD	FALCON	SYMPATHY ABORT
7506	2608	1730	11000	BUD	MIDGET	SYMPATHY ABORT
7522	0412	0230	23000	GND	ACORN	HIGH OIL PRESS NO #2 ENG 0927 SPARE
7442	1212	2035	51000	GND	BUICK	NO POWER TO ATTITUDE INDICATOR SPARED 7499
7621	2217	1330	46000	GND	SWORD	DUE TO C/L TANK LEAK SPARED BY 0842
7532	0310	0630	23000	GND	ORAMA	NO BOOST PUMP PRESSURE
7496	2210	0740	74000	GND	DEVIL	FUEL LEAK IN ENGINE COMP
7496	0810	1015	74000	GND	VEGAS	RADAR INOP
0720	1108	1305	13400	GND	MAMBON	LH BRAKE LOCKED ON TAXI ROLL
0720	0708	1240	12350	GND	RIG	COULD NOT CLOSE AFT CANOPY
0720	2308	0700	46000	GND	VESPA	LT DROP TANK LEAKING
0720	1005	1425	13250	GND	GATOR	BLEW RT MAIN TIRE
0779	0909	0415	13440	GND	ZIPPER	LEFT BRAKE LOCKED ON TAXI
0779	2109	2055	13000	GND	FRESNO	RUDDER FLUTTER
7650	1209	1245	11000	HHQ	CLIPPE	TAKE OFF TIME DELAY 20 MINUTES
7645	2808	1720	11000	HHQ	ROSCOE	TIME CHG DELAY 40MIN
7642	0808	1445	11000	HHQ	VESPA	CANCELLED AY HIGHER HEADQUARTERS
7642	1708	0550	11000	HHQ	MUSKRA	TIME READJUSTED TO 0630
7641	1809	1935	11000	HHQ	ROSCOE	LATE DUE TO CENTER LINE TANK LOOSE
7680	1709	2030	11000	HHQ	DORE	LATE TAKE OFF DUE TO ABORT OF 7586
7640	2305	1750	46000	MND	BUCKSM	RT TANK WONT TAKE FUEL
7626	1109	2030	23000	MND	CLIPPE	OIL LEAK-NO SPARE
7643	2808	1325	41500	MND	SWORD	BLC LITE CAME ON
7686	2109	0410	74000	MND	MINK SO	BOTH SCOPES BLANK
7687	2608	2155	75000	MND	HUDSON	ACFT NOT LOADED
7442	0701	1145	11000	MND	DUTCH	NO ACFT AVAILABLE
0841	2312	1355	01480	MND	RIP	TANK CHANGE
7710	1909	1850	74000	MND	LOVER	CENTER LINE BREACH STRIPPED
7659	1409	0430	11000	OPS	CLEVEL	CANX BY COL CLARK

Fig. 19 -- DEVDEG (deviation and degradation) output
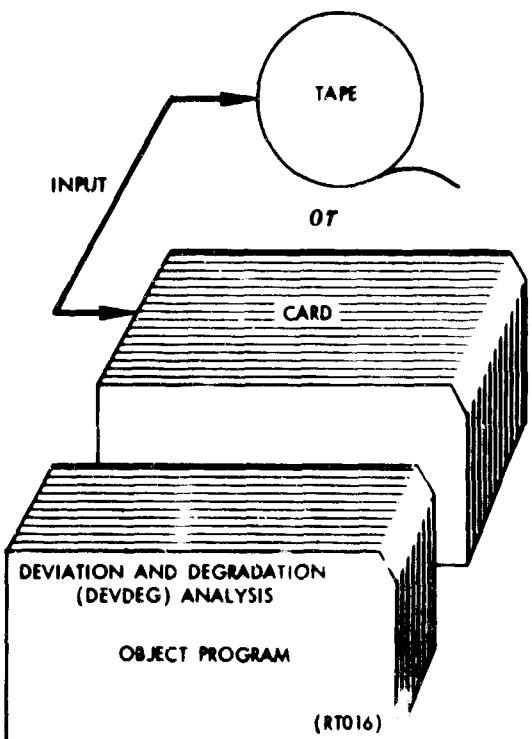
Fig. 20 -- Deviation-degradation program setup

        Major   Cols. 7-8   AN
        Minor   Col.   17   AN

If separation by system code is desired, presort by system code (Col. 46-50 AN). It is also possible to separate data by month, squadron or tail number, and so on, by post-sorting on the appropriate field.

No control cards are used. Switches I/O and A are "on" for tape data, and switches I/O, A, and B are "on" for card data.

III.   NEW DEVELOPMENTS

To this point, the text has described a fairly well developed
methodology. The techniques have been used in various situations over
a period of years, and the programs have been continually modified
through these experiences. Hence, the system described thus far is
fairly well shaken down. For the Rapid Roger project, however, we
investigated an area whe.e we had little prior experience--that of
resource allocation, in which resources were defined as personnel,
equipment, and supply. This section describes several additions to
the daily package for dealing with resource allocation problems. The
reader is cautioned that these are first trials, which themselves are
still being shaken down.

THE MANPOWER UTILIZATION SEQUENCE

Although the Manpower Utilization Sequence is a general purpose
program, we will first discuss it as a special purpose program. The
sequence relates personnel utilization (direct, on-equipment labor)
to sorties flown. Utilization is shown by shop across the 24-hour
period. Three data elements are used and described below: maximum
number of personnel used, number of personnel available, and touch-
downs. Each element is first displayed in both detail and summary
form for each work center. On the last page for each work center,
the summary data are repeated along with computations of utilization
rates. To simplify this description, it is assumed that the data are
selected for the period to be tested. Assume that one tape is used
each day.

Manpower Utilization

Place the following control card (format C12) behind the Hourly
Frequency Accumulate (HFA) program.

$$
\begin{array}{ll}
\text{Cols. 1-6} & 062066 \\
\text{Cols. 7-12} & 026026 \\
\text{Col. 79} & \text{N} \\
\text{Col. 80} & 0 \text{ (numeric)}
\end{array}
$$

Mount the work center daily 'splay tape on unit 1. Set switches I/O,
A, B and C "on", and repeat for each day's tape. The program searches
each minute of the hour to find the number of men working each minute.
When the computer senses a change in the day or in the work center, it
produces a summary card for that work center day (format W). This
card contains entries showing the largest number of men used each hour.
The computer tests each minute of each hour and retains the largest
entry. The program also accumulates the man-hours for the work center.
The output deck, identified by an "N" in Col. 80 (format W), is re-
tained for further processing.

Manpower Available

Place the following control card (format C13) behind the Compute
Elapsed Time program and mount the tail-number daily-display tape on
unit 1.

Cols. 1-3   OIE

Set I/O, A and D "on", and repeat for each day's tape. The program
selects the manpower availability data (format W), and produces a
summary card showing the number of men available for each hour of each
work-center day. This deck, also retained, has an "E" in Col. 80.

Touchdown Counts

The last summary needed is a card for each day showing the number
of touchdowns for each hour of that day. Place the following control
card (format C13) behind the Compute Elapsed Time (CET) program.

Cols 1-3   012

Mount the tail-number display tape on unit 1. Set switches I/O, A and
D "on", and repeat for each day's tape. This will select the sortie
cards.

Combine the across-midnight cards using program S/F/L. To do
this, maintain the sorting integrity. Set switches I/O and A "on".
Save the output, destroy the input. Inspect the last day of this
sample and remove any cards containing 2400 in Cols. 21-24. These

are false touchdowns: the first record of the across-midnight sortie "lands" at 2400 hours.

If the sorting integrity has been disrupted by removing the 24-hour touchdowns, resort the deck.

> Major Cols. 11-12 N month
> Minor Cols. 9-10 N day

Place a control card (format C12) behind Hourly Frequency Accumulate, as shown in Fig. 21.

> Cols. 1-6   009012
> Cols. 7-12   Flank
> Col. 79   ↘
> Col. 80   2

Set switches I/0, A and C "on". The output is the count of the landings during each hour of the day for each day of the period (format W, Col. 80=A). Destroy the input.

Utilization Display

We now have three sets of records containing summaries for each hour of the day for each day of the period:

1. The 24-hour manpower utilization records showing the largest number of men used hourly by each work center (Col. 80=N).

2. The 24-hour manpower availability records showing the number of personnel available hourly for assignment from work center (Col. 80=F).

3. The 24-hour touchdown records showing the hourly potential demands on each work center (Col. 80=A).

4. If desired, the off-equipment man-hours may be added to this display by punching up a summary card for each work center day:

> Cols. 1-5   work center
> Cols. 6-7   day
> Cols. 8-9   month
> Cols. 59-64 man-hours (in hours and tenth-hours)
> Col. 80   V

These three decks, shown in Fig. 22, are combined and sorted as follows:
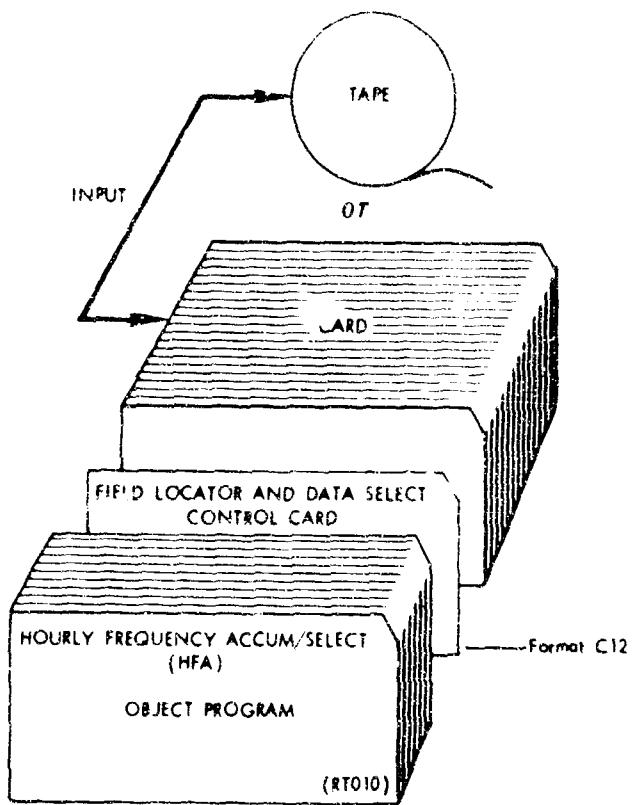
Fig. 21 -- Hourly frequency accumulate and select program setup
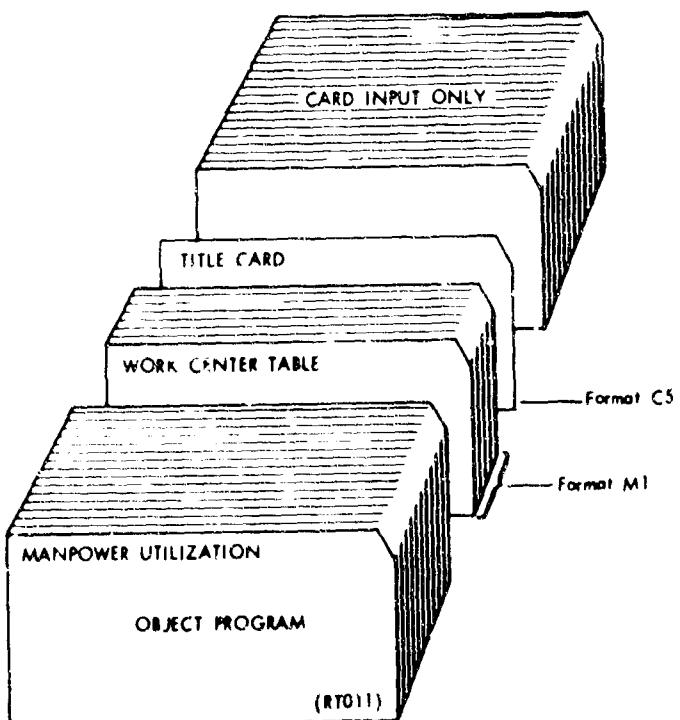
Fig. 22 -- Manpower utilization program setup

```
Major   Cols. 1-5 AN    work center
  │     Col.   80 A     card type
  │     Cols. 8-9 N     month
  ▼
Minor   Cols. 6-7 N     day
```

The deck is now ready to produce the final report. Place the table of
legal work centers (format M1) b ind the Manpower Utilizatic program.
Follow this by the manpower utilization title card (format C5) and the
data sorted as indicated. Set switches I/O and A "on".

Manpower Matrix

The Manpower Matrix program, a simplified 1401 version of a 7044
program (see Sec. IV: Sequential Frequency Distributions), provides
another method of displaying summary data created by the Hourly
Frequency Accumulate/Select program. The sample Manpower Matrix print-
out used the same set of manpower utilization processed by the Manpower
Utilization program.

The manpower matrix printout was created by sorting the input file
to the Manpower Utilization program to select all cards with Col. 80=N.
The selected deck, Fig. 23, was preceded by a title card (format C5),
punched with the data range of the data included in the sample, placed
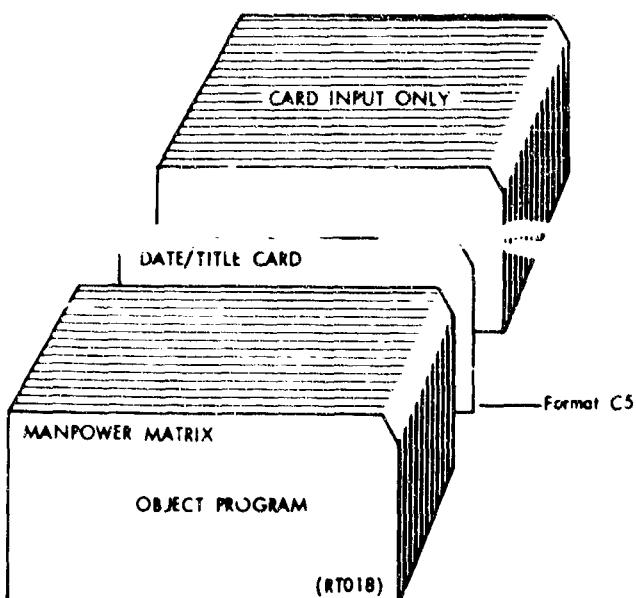
Fig. 23 -- Manpower matrix program setup

behind the Manpower Matrix program, and processed with switches I/O and A "on". The output for the complete sequence is shown in Figs. 24 through 28.

To this point, we have discussed the utilization sequence as a special purpose manpower utilization analysis. The following describes how it may be used as a general purpose sequence. Note that the Hourly Frequency Accumulate program generates two kinds of data: (1) touchdown frequencies and (2) utilization-availability frequencies. The first is characterized as a single time entry event (zero time-duration), the second as a double time entry event (start and stop time). Note further that all data in Oxnard formats fall into one of these two categories. Therefore, all Oxnard formats can be converted to the W format for similar analysis. This conversion is made possible by the frequency field selector control card (format C12) used with the Hourly Frequency Accumulate program.

In format C12, the location of the minor sense (work center in the example) is punched in Cols. 1-6. A change in this field produces a summary card. Had the program been used to summarize aircraft status, the status code location (Col. 26) would have been used. The frequency count location is punched in Cols. 7-12; this is generally team size (Col. 26). If this field on the control card is left blank, the frequency count is automatically set to "1". The card code (Col. 80 of the W format) desired is entered in Col. 79 of the control card. These codes control the output sorting sequence: to correspond with the previous sequence, use only codes A, E, and N, which the Manpower Utilization program senses. Column 80 of the control card shows the Oxnard card code to be selected.

Before processing single-entry data such as sorties scheduled or aborts, the records must be duplicated to reproduce the contents of Cols. 9-16 in Cols. 17-24. This moves the time entries into the proper field (touchdown time field) for processing through the touchdown sequence. Thus the program makes it possible to display (singly or in combination) any clock-hour information. The AGE utilization data are the first logical candidates. Sorties scheduled versus sorties flown are another. Delay codes related to sorties scheduled and sorties

DAILY SORTIE TOUCHDOWNS, BY HOUR, FOR MONTH 01

SAMPLE – MANPOWER UTILIZATION

DATE	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
09/01			2	3	1		4	1	4	2	1		1	1	6	4	3		3	3		4	
10/01	2		2	4	2			2	5	3			2	4	7				2	2	4		
11/01	4	2	2	6			6	3			5			2	9		1	2	2		4	2	
12/01		4	1	7	1		4	2	2	4	2		4	4		1	2	4		4	3	
13/01	1	4			2		6	1		3	3			2	4	5	1	4	6	1	1	3	2
14/01	1	3		2	6		4	3	4	1		3		2		2		1	1	2		2	
15/01		4	4	4	2		4	2	4	2	2	2		2	9	2	1	3	4	4	4	5	
16/01								3	7		2			6	3							4	
17/01	2	3	2		3		4	2	3		2	3	3	2	6		1	1	2	2	2	2	
18/01	2	4	2		4		4	4				1	2	2	7		1		4	2	4	1	
TOTAL	16	11	19	14	21		36	18	36	13	7	10	11	23	57	15	8	13	30	16	22	23	18
	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	1.10	1.60	1.90	2.10			3.60	1.60	3.60	1.30	.70	1.80	1.10	2.30	5.70	1.50	.80	1.30	3.00	1.60	2.50	2.40	1.90

Fig. 24 -- Manpower utilization: touchdown summary

(Touchdowns are shown for each hour of the day at the end-hour--the midnight to 0100 counts appear under "01". One line is given for each day, with the touchdowns per hour under "AVG" on the right. At the bottom are the count totals for each hour. These totals are divided by the number of days to give the averages for each hour of the day. Note the wide variations in the daily counts, particularly from 1100 to 1700 hours.)

DAILY MANPOWER AVAILABLE, BY HOUR, FOR MONTH 01

WORK CENTER 12041   TESTSQ FLIGHT LINE FLIGHT =A SECT 1   SAMPLE - MANPOWER UTILIZATION

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AVG
09/01	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	10	10	10	10	10	10	10	10	12.66
10/01	14	14	14	14	14	14	14	16	16	16	16	16	16	16	15	16	10	10	10	10	10	10	10	10	13.41
11/01	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	10	10	10	10	10	10	10	10	12.66
12/01	13	13	13	13	13	13	13	16	16	16	16	16	16	16	16	16	11	11	11	11	11	11	11	11	13.45
13/01	13	13	13	13	13	13	13	15	15	15	15	15	15	15	15	15	13	13	13	13	13	13	13	13	13.75
14/01	13	13	13	3	13	13	13	16	16	16	16	16	16	16	16	16	12	12	12	12	12	12	12	12	13.79
15/01	13	13	13	13	13	13	13	15	15	15	15	15	15	15	15	15	11	11	11	11	11	11	11	11	13.08
16/01	14	14	14	14	14	14	14	15	15	15	15	15	15	15	15	15	11	11	11	11	11	11	11	11	13.37
17/01	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	11	11	11	11	11	11	11	11	12.33
18/01	14	14	14	14	14	14	14	12	12	12	12	12	12	12	12	12	11	11	11	11	11	11	11	11	12.25
TOTAL	35	135	135	135	135	135	135	146	146	146	146	146	146	146	146	1.6	110	110	110	110	110	110	110	110	13.07
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
	13.50	13.50	13.50	13.50	13.50	13.50	13.50	14.60	14.60	14.50	14.60	14.60	14.60	14.60	14.60	14.60	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	
	13.50	13.50	13.50	13.50	13.50	13.50	13.50	14.60	14.60	14.50	14.60	14.60	14.60	14.60	14.60	14.60	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	

Fig. 25 -- Manpower utilization: manpower available

(The entries, ...ries and summaries follow the same format as Fig. 20. The data show that availability is low in the "B" shift, 0730-1630 hours, and high in the "C" shift, 1630-2400 hours.)

DAILY MANPOWER UTILIZED, BY HOUR, FOR MONTH 01

SAMPLE -- MANPOWER UTILIZATION

WORK CENTER 12C61   TESTSQ FLIGHT LINE FLIGHT =A SECT 1

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AVG
09/01	3	6	7	5	4	5	4	15	10		3	9	5	6	11	7	4	9	6	9	10	9	9	9	7.00
10/01	4	3	9	9	8	7	5	11	9	12	7	10	6	6	9	9	8	6	6	8	7	7	6	8	7.50
11/01	6	8	12	3	4	6	8	13	10	11	9	15	9	10	9	7	8	9	4	9	5	4	7	6	8.00
12/01	9	5	6	10	7	9	13	5	14	15	8	7	11	15	10	14	12	13	8	9	8	8	10	8	9.54
13/01	12	5	8	12	8	7	5	11	11	7	15	10	8	11	10	4	6	8	7	3	8	3	9	4	8.08
14/01	4	5	7	3	11	8	12	8	10	11	9	9	7	6	9	9	13	8	11	4	4	7	4	3	7.75
15/01	7	7	7	1	3	8	5	13	8	15	14	11	14	15	11	11	12	14	10	12	3	6	6	7	8.54
16/01	9	11	11	5	6	15	12	9	14	20	13	12	10	10	16	11	17	10	5	3	9	3	9	8	10.12
17/01	8	7	3	10	11	8	11	18	21	16	8	10	7	13	6	12	9	5	5	8	7	10	6	6	9.17
18/01	14	11	9	8	3	6	8	10	10	11	8	8	3	9	8	11	14	9	6	4	7	7	6	3	8.08
TOTAL	76	45	76	66	43	72	83	113	117	126		100	80	100	93	93	101	90	68	76	72	63	72	62	8.40
	7.60	6.40	7.00	6.60	4.45	8.20	8.30	11.40	11.70	12.60	9.40	10.00	8.00	10.00	9.30	9.30	10.30	9.00	6.90	7.60	7.20	6.90	7.20	6.20	

Fig. 26 -- Manpower utilization: manpower utilized

(Format is the same as in Figs. 20 and 21. Note that the detail shows the largest number of men at work during each hour, not the largest number of teams.)

WORK CENTER -12/9A/- AVERAGES AND UTILIZATION RATES FOR MONTH 01   SAMPLE - MANPOWER UTILIZATION

TESTSO FLIGHT LINE FLIGHT .A SECT T

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
TOUCHDOWNS -AVG-	1.10	1.10	3.60			1.80	1.30		1.40		1.80	2.30		1.50		1.30	1.60	2.50	2.40					
		1.60	1.90	2.10	3.60	3.50		1.60	3.60	1.10	.70	2.70	.80	3.00	1.80									
AVAILABLE -AVG-	13.50	13.50	13.50	13.50	14.60	14.60	14.60	14.60	14.60	14.60	14.60	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00					
		13.50	.50	13.50	14.60	14.60	14.60	14.60	14.60	14.60	14.60	11.00	11.00	11.00	11.00	11.00	11.00							
UTILIZED -AVG-	7.60	7.0	4.90	8.33	11.70	9.40	8.00	9.30	10.30	6.40	7.20	6.20												
		6.80	6.40	8.20	11.30	1.60	10.00	10.00	9.30	3.00	7.60	6.10												
UTIL RATE	.56	.52	.36	.41	.80	.64	.55	.64	.94	.67	.65	.56												
		.50	.49	.61	.77	.86	.68	.68	.64	.87	.69	.57												

DATA DAYS THIS MONTH

FLYING - 10
AVAILABLE - 10
WORKING - 10

TOTAL SORTIES - 480
FORM 300 TOTAL MANHOURS - 1,293.1
MANHOURS PER SORTIE - 2.7
AFTO 211 TOTAL MANHOURS - 2.2
AVAILABLE MANHOURS - 3,139.0
AVG MANHOURS UTIL - .41

AVG PERS UTIL - .64

Fig. 27 -- Manpower utilization: summary

(The average per hour summaries from the bottoms of Figs. 23, 24 and 25 are repeated to aid the cross-comparison. The entries to the right of "Util Rate" are computed by dividing the utilized averages by the corresponding available averages. These utilization rates are summed and divided by 24 to give an unweighted average across the clock. Note that the highest utilization rat.s occur during the "B" shift, which has the lowest availability. The entries under "Data Days" show the sample sizes. For this particular output, the off-equipment man-hours were added (AFTO211...) to the form 300 totals and an overall utilization rate computed by dividing the total used by the total available.)

Fig. 28 -- Flight-line demands throughout the 24-hour day

(The ordinate gives the team size, the matrix gives the number of demands.)

flown might prove interesting. In short, the program can be used to display any clock-hour data and thus can inspect the ebb and flow across the 24 hours of the day. See also Sequential Frequency Distributions, Sec. IV.

The Manpower Utilization Sequence was initially developed to help the base manager make a better hourly distribution of his available manpower. The first set of real-world output made it apparent that the manpower sequence would be useful for addressing a much more profound problem--that of personnel assignment, which concerns how many of what skill should be assigned to the wing. The first time the sequence was used in this area, it uncovered a serious misalignment between available and utilized personnel. Some work centers were seriously undermanned and could meet demands only by prolonged overtime. Others were so grossly overmanned that there was concern over workforce morale because of the inactivity.

Remember that experience with the sequence is limited. As yet, there has been little chance to determine the relative importance of the various elements of the analysis and, hence, little chance to modify the sequence accordingly. The following items bear directly on further explorations with the sequence.

1. Utilization rates should be approached cautiously. They can be quite helpful in resolving the shift assignment problem--for example, matching the 24-hour distribution of manpower availability with the 24-hour distribution of potential demands (touchdowns).

   However, using them for the complex personnel assignment problem is another matter. How many men with what skills to assign to the various work centers is a function of the flying program. The nature of the relationship is not well understood. As far as utilization rates are concerned, it is certainly not linear. For certain, adjusting assignment to get 40-percent utilization in all shops is not a desirable solution.

2. Utilization rates may exceed 100 percent. This will occur when overtime is required. Persistent occurrence indicates improper shift assignment, inadequate manning or both.

3. Off-equipment work must be included in manpower assignment considerations. The bench load of some shops, such as radar, is often greater than the flight-line load. And bench load is not always low priority work; some bench fixes will be priority I, as discussed below.

Items 4 and 5 refer more to the specific methodology.

4. The operational definitions must be understood. The peak
    utilizations are not identical to demands. Utilizations
    reflect demands "smoothed out" by the scheduling process.
    Note, too, that the average demand rates on the final
    page give no hint of the variance. This shortcoming may
    be partially circumvented by referring to the daily
    detail listing procedure.

5. The program assumes that each work center has 3-shift
    manning. The average availability computations will
    be affected where this is not true. Note, too, that
    not all the availability data come from the dispatch
    board in job control. Special arrangements must be
    made to obtain the availability data for crew chiefs,
    munitions, tank farm, etc.

AGE UTILIZATION

This is a special purpose program designed to show flight-line
AGE utilization (both active and standing). Initially, the plans
were to display this data like the manpower utilization displays,
i.e., showing touchdown patterns and availability juxtaposed with
utilization. It quickly became apparent that AGE had unique charac-
teristics that could be approached better by concentrating on AGE
management.

Using program CET, select the cards containing an F in Col. 80
(format S). These are sorted as follows.

Major	Cols. 65-66	H	AGE
	Cols. 11-12	N	month
	Cols. 9-10	N	day
Minor	Cols. 13-16	N	hour-minute

This deck is placed behind the AGE display program, as shown in Fig.
29. No control card is necessary. Switches I/O, A, and B are set
"on" for card input.

The AGE display in Fig. 30 shows that a given piece of equipment
may be used several times during a fix. Hence the utilization dura-
tions would probably best be represented by taking the first time
spotted or used as start time and the last time used or removed as
the stop time. Until a program is available that combines the AGE
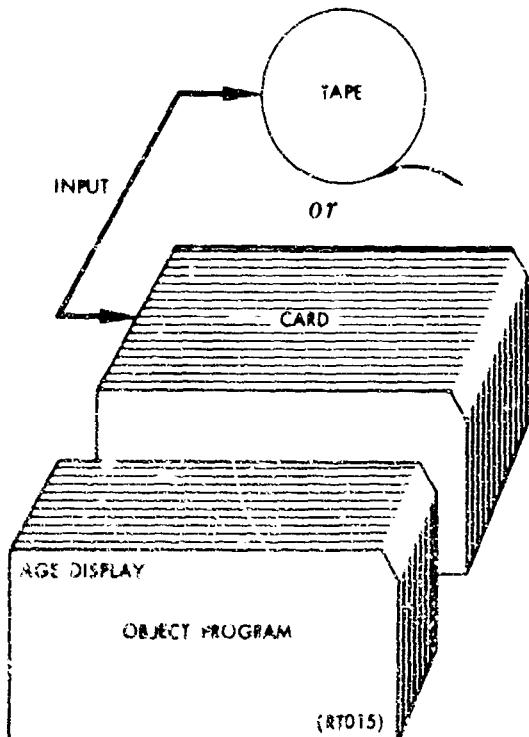
Fig. 29 -- AGE display program setup

used on a fix, the "by tail-number utilization" can be observed by a change in the sorting.

```
Major   Cols. 65-66  N    AGE code
        Cols. 11-12  N    month
        Cols.  9-10  N    day
        Cols. 35-38  N    aircraft tail-number
Minor   Cols. 13-16  N    hour-minute
```

AGE analysis is complicated because three kinds of AGE are used.

1. Dispatched AGE. "Owned" by the flight-line and used on the flight-line.

2. Nondispatch AGE. Carried from the work center and used on the flight-line.

3. Nondispatch AGE. Used only by the work center in the shop.

AGE analysis is als complicated because items range in cost from several dollars to several hundred dollars. Our attempts to deal with these factors were certainly far from satisfactory. They are offered onl as a point of departure for designing a better system.

Fig. 30 -- AGE Utilization

("A" shows the AGE being used. An "A" is always printed in the 15-minute matrix cell even if used less than 7½ minutes. The dots preceding and following an "A" show the time the AGE was standing by the aircraft without being used. The using work center is shown under the column heading "WC". The summaries below show the counts of the 15-minute matrix cells in which an "A" appears, hence the actual number of AGE in use at any point in time might be less (but never more) than this entry. These data are analyzed by processing them through the manpower utilization sequence.)

Dollar value of AGE is determined from the base inventory list that BEMO (Base Equipment Management Office) provides. Based on an arbitrary decision, a list consisting only of items exceeding $1000 was selected. Two separate tables of AGE codes were constructed from this list, one for field maintenance (FMS) and one for armament and electronics (A&E).

Flight-line AGE utilization was recorded by a special team of data collectors, using RR form 304. Be assured that this was costly; it took 18 recorders to cover a wing of aircraft on a 24-hour operation. Although the data were excellent, the sampling had to be limited.

Bench AGE utilization was obtained by having the user enter the AGE code and number of users in Block L of the AFTO 200 forms immediately under the phrase "corrective action"; for example, 13/2 indicated that the team size yielded the elapsed time. Although there was no way to cross-check the bench utilization, the consensus of the Rapid Roger data collection group was that this method of collecting bench AGE was unsatisfactory because of erratic recording.

Two more statements are possible. First, once AGE utilization data are available, the list of items to monitor can be reduced. The basic question is how many of a given type are required. Items needed only once can be culled from the survey. Second, once the determination is made for frequently used items (need for more than one), undoubtedly some rewarding cost-effectiveness studies can be made in which cost is measured in dollar value of the AGE inventory and effectiveness is measured in speed of aircraft turnaround.

"ON-EQUIPMENT" BENCH REPAIR

At times, maintenance personnel remove an item from the aircraft, take it immediately to the bench, fix it, and replace it on the aircraft. As a result, the item does not go through conventional materiel control channels in a priority IV status. Rather, the bench repair becomes an integral part of priority I (on-equipment) action.

We discovered that we could include bench repair in the on-equipment data bank by making some minor additions to the recording procedures: enter the start and stop times on the AFTO 211 form (copy 1) along with

the team size. These 211's are keypunched in form 300 format, using
code "B" in the work order prefix, edited and included in the data
bank. When discovered code "Z" identifies the bench repair data, and
is used to avoid contaminating the K-97 deck, which includes the same
information on copies 3 and 4.

The priority I bench repair actions are also correlated with the
flight-line actions using the ETR (equipment temporarily removed)
delay code. The sequence of actions is the following:

1. Remove the item using the action taken "P" on the 300 form.

2. Start the delay on the 300 form using the ETR code.

3. Fix the item at the bench. Record start time, stop time,
   team size, and actions taken on copy 1 of the 211.

4. Return to the aircraft and terminate the delay on the 300
   form.

5. Install the item using action taken "Q" on the 300 form.

This entails a lot of recording. Were we to use it again, we would
probably use one line of the ETR delay and one line of the 300 form,
starting with the removal and ending with the installation for the
fix action.

IV. 7044 PROGRAMS NOT YET AVAILABLE FOR 1401

There are several 7044 programs that would be desirable inclusions in the maintenance analysis package for base-level management. Unlike the methods described in Sec. III, these have all been used in a number of different settings, and most of the developmental problems have been resolved. However, they have not yet been converted to the 1401.

SPLATTERGRAMS

By displaying the write-ups sortie by sortie, the Splattergram program gives a snapshot history of each aircraft. It computes the write-up rates for each aircraft and prints them at the end of each tail-number. Tail-number data are then accumulated for the squadron and printed as squadron write-up rates on the last page of output. These data are saved and used to obtain repeat write-up evaluations as described below in the system repeat write-up analysis.

Because of interest in the Splattergrams, a number of variations have been developed, particularly for use with debriefing forms. The current display shown in Fig. 31 reads from top to bottom instead of from left to right, as did the original. The top to bottom sequence makes the program easier to adapt to a small computer, since the data may be processed and printed a record at a time.

Although this program can be used to process the special tape record output by Clint (containing the system break summaries by sortie), it will prove more useful for handling debriefing data, particularly when the data include the "system not used" distinction as does the 1-SAC-U82 data, for example. Note that the break-rates produced using the special Analysis of Variance program are erroneous when the data include systems not used on all sorties, and must be corrected by using the data provided by the intermittently used systems debriefing form. The Splattergrams provide automatically for this correction.

Fig. 31 -- Splattergrams

The tail number, day, month and sortie type are shown in the fields along the left margin. A "1" in the matrix indicates a write-up for the system indicated by the mnemonic codes along the top. The "SYS RPT" entries show the counts of write-ups followed by write-ups.

SYSTEM REPEAT WRITE-UP ANALYSIS

Two RAND studies suggest the usefulness of being able to determine, by statistical methods, whether repeat write-ups are occurring in nonrandom fashion.* These studies cluster write-ups by system (e.g., a write-up on landing gear system) rather than by the conventional part write-up; however, the technique employed requires sample sizes too great to be of practical use. To circumvent this, the following method was devised.

Given a sample of 50 sorties, assume that the radar system is written up 15 times. The proportion of write-ups (P= 15/50 = 0.30) can be used to predict the theoretical number of times that a ite-up would follow a write-up if only random effects were operating-- (0.30)(0.30) = 0.09. This reasoning can be extended to apply to all pairs of events. Assume a write-up is coded "1" and no write-up is coded "0"; then when we sweep down through the Splattergram, we would expect on the average that

"1" would follow "1" (0.30)(0.30)(50)=4.50 times
"1" would follow "0" (0.30)(0.70)(50)=10.50 times
"0" would follow "1" (0.70)(0.30)(50)=10.50 times
"0" would follow "0" (0.70)(0.70)(50)=24.50 times.

The numbers derived from the calculations can be used as theoretical frequencies (expected values) t be compared with actual data counts. This is done by the program. As each new record is read in, it is compared with the previous record to determine whether a "1" followed a "1", etc. The expected values are determined as described and a Chi-square test is made, as illustrated in Fig. 32.

To reduce meaningless output, the program suppresses the printing of systems analyses that have no repeat write-ups in the sample. The 7044 program combines the Splattergram and the Repeat Write-up Analysis, and also accounts for the "system not used" codes (such as used in the 1-SAC-U82 data). In this instance, the repeat write-up analysis

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*See W. H. McGlothlin and T. S. Donaldson, Trends in Aircraft Maintenance Requirements, The RAND Corporation, RM-4049-PR, June 1964, and A. F. Sweetland and T. S. Donaldson, Trends in F-101 Aircraft Maintenance Requirements, The RAND Corporation, RM-4930-PR, April 1966.

32-MADAM

	OBSERVED FREQ	THEORETICAL FREQ	D2/ET	P OBSVD	P THEOR
1-1	103	74.667	10.937	0.099	0.071**
1-0	176	204.225	3.368	0.171	0.196*
0-1	171	204.225	5.405	0.164	0.196**
0-0	591	560.082	1.707	0.567	0.537
		CHI-SQUARE =	21.412***		

Fig. 32 -- System repeat write-up analysis

(The "1-1" entry indicates a write-up followed by a write-up. The count of times this happens is shown under "OBSERVED FREQ". The theoretical frequencies are calculated as described in the text, and the theoretical proportions are obtained en route (e.g., "P THEOR" = (.30)(.30) = .09 and "THEORETICAL FREQ" (.09)(50) = 4.5) The observed proportions (P OBSVD) are obtained by dividing the observed frequencies by the number of pairs of sorties.)

can come as quite a shock: the Splattergrams suggest that the systems used only occasionally appear to be reasonably healthy. But the analysis program proves otherwise. This inevitably produces some hasty reviewing of the Splattergrams with some reorientation of perception on the "system not used" information.

WORK UNIT CODES ANALYSIS (5-DIGIT SUMMARIES)

The work unit code analysis summarizes on one page all the meaningful information on form 300 records. The need for the summary stems from several sources--most often from the desire to understand the role that hardware plays in write-up and recovery rate phenomena. The program builds a histogram of elapsed time distributions using team-size to delineate the histogram, as shown in Fig. 33. As with the other histograms, the percentage of jobs completed by a given hour is shown. The program determines the number and kinds of action taken, when discovered, and how malfunction codes encountered in the data sample. These counts are shown in order of descending frequency. Abbreviated verbal definitions of the how malfunction codes are included in the output. In addition to the usual computations--counts, totals, and means--the break-rate is also computed by reading in the sortie count or other appropriate base-line.

To avoid excessive and useless output, some rational basis is needed for selecting the work unit codes to process. Otherwise, the typical data sample of form 300 records will contain 600-1000 different work unit codes resulting in 600-1000 pages of output. As a first approximation of what to select, use program FREQ (see Sec. II) to obtain frequency counts of the work unit codes, and select only those codes that occur frequently enough to yield meaningful distributions.

This program assumes that the across-midnight records have been combined into one record or else eliminated. Data should first be tested for presence of stop times of 2400 and start times of 0001 which would indicate non-combined records.

Fig. 33 -- Five-digit work unit code summary

(The entry "Avg" shows the average elapsed time. "Avg Man Hrs" is the average for each job. "Total" gives the total (net) fix time.)

SICK BIRD ANALYSIS

Maintenance management always want: o know if they have any aberrant aircraft in their system. The sick bird program attempts to provide this information.

In general, aircraft problems show in the break-rate data before they show in the recovery data. The sick bird isolation determines whether individual tail-numbers show atypical write-up rates based on the number of sorties flown by obtaining the sortie and write-up counts for each aircraft and, using Chi-square, testing for non-homogeneity. Although hours flown has been used as a base-line for the Chi-square test, current investigation indicates that sorties flown is preferable, since hours flown can lead to erroneous conclusions.

Because most analyses are based on a month's flying, there are sampling problems when the data are separated by aircraft. If the 2-digit systems are used as a basis of calculation, the frequency counts are often too low to yield valid statistical determinations. And if the entire aircraft is used, desirable detail is lost. The sick bird approach attempts to overcome this by fractioning the data at a level between the aircraft and the 2-digit systems. Most often the write-ups are accumulated into six categories: aircraft basic, propulsion system, utilities, instrument-autopilot, communication-navigation, and weapons.

Based on the particular TMS, the instrument-autopilot, communications-navigations classifications are adjusted to give accumulations that are logically and statistically meaningful. For example, with simple aircraft they might all be combined in one group. The pre-processing program is adjusted to record the particular 2- or 3-digit system so that it may be processed appropriately. For example, the 2-digit systems

> 11000 Airframe
> 12000 Fuselage
> 13000 Landing gear
> 14000 Flight controls

are all coded "1" as basic aircraft. While this is going on, the

AUGUST BASIC AIRCRAFT WRITE-UPS/SORTIE

SAMPLE 1 -MAJOR-

BASE-LINE	FO	FT	D2/FT	MEANS	-3	-2	-1	0	1	2	3	4	5
8	52	12.33	127.70***	6.500						268			
7	8	10.79	.72	1.143			312.						
8	27	12.33	17.47***	3.375					367				
7	15	10.79	1.65	7.143				413					
21	16	32.36	8.27**	.762		419.							
14	3	21.57	15.99***	.214		426							
11	40	16.95	31.35***	3.636					428				
10	1	15.41	13.47***	.100		43?							
8	3	12.33	7.06**	.375		434							
8	13	12.33	.04	1.625			436						
17	23	26.19	.39	1.353			438.						
13	1	20.03	18.08***	.077		439							
17	10	26.19	10.01**	.588		440							
18	6	27.73	17.03***	.333		441							
11	49	16.95	60.61***	4.455						442			
15	21	23.11	.19	1.400			444.						
11	39	16.95	28.69***	3.545					449				
17	13	26.19	6.65**	.765			451.						
6	13	9.24	1.53	2.167				260					
6	6	9.24	1.14	1.000			287.						
TOTAL													
233	359			1.541					1.778 -UNWEIGHTED-				

WEIGHTED GRAND MEAN--
CHI-SQUARE-- 368.02
DF-- 19

THE PROBABILITY IS BEYOND THE 0.001 LEVEL. THE DISTRIBUTION IS NOT HOMOGENEOUS.

Fig. 34 -- Sick bird output

(The base-line shows the number of sorties flown. FO and FT are the observed and theoretical frequencies. D2/FT is the difference between FO and FT squared and divided by FT squared and divided by FT. Means are FO divided by the base-line, i.e., average per sortie. The means are converted to Z-scores and plotted around their unweighted grand mean in the display at the right. Asterisks indicate statistical significance levels.)

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program is also accumulating several summaries for each aircraft: sorties flown, hours flown, man-hours utilized, write-ups, and total down time. Then these summaries are input to the Chi-square program (see Fig. 34).

When the sick bird analysis indicates a problem, the next step in diagnosis is to check the Splattergrams to isolate the problem by system and by date. After that the daily displays are checked. If further information is desired, the 781's in aircraft records and/or the 992's in the various shops are scrutinized. The crew chief, of course, will have much anecdotal material.

SEQUENTIAL FREQUENCY DISTRIBUTIONS

The Sequential Frequency Distribution program summarizes and displays events across 24-hour periods. Its inputs have the same format as those for the Manpower Utilization Summary, which are the frequency counts for each hour of the day. The program creates a frequency distribution for each hour and displays it vertically to reveal the ebb and flow of daily events, as shown in Fig. 35. The display also indicates the frequency and magnitude of unusual occurrences, thus alerting management to the extremes that it can expect. This is generally the first step in formulating procedures for dealing with a dilemma. The display is used extensively in manpower and AGE utilization analyses.

Most processing needed to generate this display is contained in the Manpower Utilization Sequence. This is a collection of summary records of zero time duration events such as touchdowns, schedule deviations, and other data that do not have both start- and stop-time entries. The Hourly Frequency Accumulate program also produces summary records for data having both start- and stop-time entries: manpower utilized, AGE utilized, sorties flown, lags, delays, fix times, aircraft status, and so on. The Sequential Frequency Distribution program may display both types of data. For more detailed work-center analysis, a special version of this program is used. Time zero is set to touchdown time instead of midnight, thus orienting the summary to sorties rather than to shifts.

WORK CENTER 331   DATE 10

NO.-MEN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
19																								
18																								
17																								
16																								
15																								
14																								
13														1										
12																								
11								1									1							
10															2	3	1	1	1	1	1	3		
9		2							1		1	1	1	3	1	1	2	1	2	1	4	3	5	1
8			1	1					2	2	3	2	3	2	1	3	2	4	3	3	4	1	1	1
7			1	6	4	3	4	5	1	1	1	4	1	2	4	3	3	4	2	4	1	9	7	7
6	2	1	2		4	1	4	2	2	2	2	2	3	2	2	2	1	3	5	2	2	1		
5		1	3			3		7	1	8	6	8	4	3	5	4	6	2	6	7	6			
4	2	1				1		1	2	1		2	7	6		1	5	1		1				
3	1	1						1	1	3	3	3	1		1	6	1	3		2		7	1	1
2	2	1						1	1	2	1	3			2	1	5	2	5	7	2			
1	1	1																						
0	23	23	23	22	25	24	21	11	7	12	13	8	10	10	9	6	5	8	10	9	11	12	15	20
MEAN	0.6	0.8	0.6	0.5	0.3	0.3	0.7	2.1	2.3	1.9	1.8	2.3	2.9	3.1	4.0	4.0	4.0	3.7	2.9	2.6	2.5	1.8	1.3	0.7
MEAN																								
SIGMA	1.2	1.1	1.1	0.9	0.7	0.8	1.1	2.2	2.3	1.9	2.2	2.6	3.3	3.3	3.7	3.2	3.7	3.2	2.8	2.3	2.5	1.9	1.5	1.1
SIGMA	1.7																							

Fig. 35 -- Flight-line demands throughout the 24-hour day

(The ordinate gives the team size; the matrix gives the number of demands.)

MULTIVARIATE METHODS

From time to time we have used several of the BIMD programs written by the Department of Preventive Medicine and Public Health, School of Medicine, UCLA. Two have proven quite useful--Multiple Regression and Factor Analysis. Currently, we are testing several multiple regression programs available for the 1401. Should one prove suitable, it will be included in the program package. Thus far, we have been unable to locate a Factor Analysis program adaptable for the 1401.

V. FURTHER PROGRAMMING NEEDS

Extensive analysis with the RAND/TAC system has revealed that the greatest weakness of the maintenance package is in the area between the software the manufacturer provides (e.g., merging and sorting routines) and the programs. The missing elements are extensions of routines normally described as PCAM actions--those concerned with selecting subsets of data, tagging data, relocating data fields, and so on. The needs also include a simplified report generator, since most report generators require too much training to be used by those with no programming experience. These needs are described in the following sections.

REPORT GENERATOR

The program described now supplies a report generator so simple that most people can learn to use it in less than 15 minutes if they understand simple sorting concepts--majors, intermediates, and minors. Most of the material is in cont 1 card form, and is easy to learn because the output is restricted to fixed field locations.

Major	Cols. 1-15
Intermediate	Cols. 16-30
Minor	Cols. 31-45
Data	Cols. 46-60

The analyst provides four or fewer control cards, using the Report Generator Instruction Sheet as indicated in Fig. 36.

1. A general title card, which may be omitted.

2. A field identification (field header) card, which may be omitted.

3. A field location card, which is mandatory. This locates the low- and high-order positions of the major, intermediate and minor control fields and the data. It is not necessary to use all three control fields; any combination can be used. The output will appear in the location defined. For example, if a field location is given only for the intermediate, i.e., punched in Cols. 25-30 of the field location card, with blanks in Cols. 10-15 (major location) and Cols. 40-55 (minor location), only the intermediate field will be sensed and printed and it will appear, right-justified, in Cols. 16-30 of the output.

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Fig. 36 -- Report Generator Instruction Sheet

4. An edit mask card. This locates the decimal place which is
   edited into the data field just before printing. If this
   card is omitted, no editing transpires (the program assumes
   the data are in whole numbers).

The desire to include this program in the package is entirely
defensive. The biggest constraint in any computer venture is program-
mer time, and the biggest time consumers are individuals who are naïve
in data processing. So we are attempting to relieve the programmer of
unnecessary work (the bulk of programming requests are for special
listings) and to begin simultaneously to overcome some data processing
naïveté. Obviously, the individual who tries out various data combi-
nations before he contacts the programmer has a better chance of get-
ting a working program than the person who uses the programmer as a
loop in a sequence of trials and errors.

As visualized, the Report Generator program reproduces the field
location information on page 1 of the output to facilitate cross-
checking. Output includes record counts, totals and means. In addi-
tion, the summary data include both nonzero and total record counts,
as well as their corresponding means.

DATA SELECTING, TAGGING, AND REFORMATTING

Most projects and exercises reveal the need to handle data in a
new and different manner. Frequently, new files of information must
be added to the data bank or subsets of old files must be extracted
and processed in a different way. An example would be the need to
add the Forward Air Controllers report (or the Range Report Data) to
the data bank to determine whether any interrelationships occur.

The program we have in mind, shown in Fig. 37, accepts a set of
control cards such as shown below. Translated, the input block size
and record length is 1 and 80. The output record length is 1320 char-
acters long (a block of 10 records of 132 characters each).

INPUT RECORD BLOCK SIZE
OUTPUT RECORD BLOCK SIZE

LEGAL CODES COLUMNS 1-4

BLKI
BLK0
IF
AND } Left Justify
MOVE
PLUG
OUTP
END

LEGAL CODES COLUMNS 14-15

EQ - Equal
GT - Greater Than
LT - Less Than
EG - Equal or Greater Than
EL - Equal or Less Than

(Leave Cols. 14-15 blank for PLUG or MOVE commands.)

If blanks are to be Plugged, leave Cols. 17-34 blank.

Columns 5, 13, and 16 must always be blank.

Column Locations must be preceded with zeros.

MOVE must have "X" (11 punch) in Col. 20.

*Records must be in Control Deck.

Fig. 37

```
BLKIN 01X080
BLKOU 10X132

IF      080-080 EQ 0
AND     011-012 GT 06
AND     011-012 LT 20
PLUG    081-084     ABCD
MOVE    035-038     085-088
OUTP

IF      080-080 EQ 2
MOVE    002-005     085-088
OUTP

END
```

Two "if-output" sets of conditions (if-and) and commands (plug, move and outputs) are used. The first tells the computer that if Col. 80 contains a zero and the contents of Cols. 11-12 are greater than 06 and less than 20, plug (tag) "ABCD" into Cols. 81-84 and move the contents of Cols. 35-38 to Cols. 85-88. On sensing "OUTP", the computer outputs the new record. If the conditions of the first "if-and" set are not met, the computer moves to the next "if-output" set and tests: If Col. 80 contains a "2", Cols. 2-5 are moved to Cols. 85-88 and this record is output. If no conditions are met before sensing the "END" card, a new record is read and the sequence iterated. The output tape can now be sorted on Cols. 85-88 and processed in the usual manner.

The program thus allows the user to select any subset or subsets of data from a data bank consisting of mixed formats, tag each of these in any manner desired, and move any data fields into a common format for sorting and processing.

SELECT DATA BY MATCHING FILES

Occasionally, there may be two files (tapes) of records, one containing the desired characteristics and the other containing matched sets of data (desired) as well as a number of undesirable records. This would occur when we wished to select maintenance records that match a discrete set of operations records. Before using, both tapes are sorted on the appropriate fields. The control cards would look like those shown below.

```
BLKIN 01X084
BLKOU 01X084

IF     018-019 EQ 023-024
AND    050-052 EQ 050-052
OUTP

END
```

Translated, the inputs are single records 84 characters long; the out-
puts are identical. The conditions and commands are translated as
follows. If the contents of Cols. 18-19 on tape unit 1 equal the con-
tents of Cols. 23-24 on unit 2, and also Cols. 50-52 of unit 1 equal
Cols. 50-52 of unit 2, the record on unit 2 is written on tape unit 3.
The ultimate program should be able to handle match-selections of
greater complexity than that indicated by the example.

General Purpose List

When beginning an analysis, the analyst spends much time poring
over the queue sorts (which show the data pictorially) and a straight
listing of the data, record by record.[*] More often than not, he
wished to check blocks of data in the listing. A block is defined
here as all the data containing a common element--a specific sortie,
tail number, mission type, etc. These data blocks are amazingly dif-
ficult to locate in the mass of output given on an 80-80 listing. We
would like to be able to offer the computer the following.

```
BLKIN   10x84
BLKOU    1x84
SKIP   035-038 1
SKIP   001-001 3
END
```

The translation of input and output block size and record length
is as before. If a change is sensed in the contents of Cols. 35-38,
one space is skipped on the printout. Similarly, a change in Col. 1
would cause three spaces to be skipped. The data, of course, must be
sorted first on the fields to be tested. As a general statement,

---

[*] This is generally referred to as an 80-80 listing, although
record lengths often exceed 80 characters.

changes in the major field are associated with the SKIP 3 instruction,
intermediates with SKIP 2, and minors with SKIP 1.

The Spread-Field List

The spread-field list provides a listing of each field isolated
from the adjacent one by blanks, thus easing the eyestrain of the
error editor. Thus the spread-field listing of the 300 form records
would appear as shown:

TAIL	SU	DAMO	B/W/C	RPTNO	
7444	FJ	1016	21231	14515A	
7444	FJ	1016	22312	14515B	etc.
7444	FJ	1016	24311	14515C	
etc.					

Spreading the 80-80 listing so that it corresponds to the field
separation of the record forms materially facilitates the cross-
checking process. The spread-listings should be double-spaced so the
editor can enter his corrections (preferably in red) under each aber-
rant entry. Each recording form requires a program. The field heads
should be identical or very similar to the entries on the recording
forms, and should appear at the top of each page. (Note that with the
addition of the capability of printing title cards, the Select, Tag
and Reformat program could produce this.)

INTERSPERSED GANG-PUNCH EQUIVALENT

There is one desirable addition to the package of software--the
computer equivalent of an interspersed gang-punch. This is needed
when two different sets of data exist and entries from one set must
be transcribed onto the records of another. Thus we might have a
multiple format record consisting of Op-Rep 4 records and sortie de-
scription data and we wish to copy the target characteristic from the
Op-Rep 4 into a blank field on the sortie data. Assume we have used
the Select, Tag and Reformat program and have built a set of records
as shown below.

```
Op-Rep 4 24542 (located in Cols. 131-135)
Sortie    (blank)
Sortie       "
   "         "
Op-Rep 4 24543
Op-Rep 4 24544
Sortie    (blank)
```

The following control cards would be used:

```
BLKIN 10x138
BLKOU 10x138
GANG  131x135
END
```

The computer reads in records until it finds a non-blank entry in
Cols. 131-135. It stores this entry and "gang-punches" it into Cols.
131-135 of all subsequent records containing a blank in Cols. 131-135.
On sensing a non-blank, it stores this new entry and continues. We
are not so optimistic as to feel that the final version of this pro-
gram would be so devoid of checks. Thus far, we have always had to
write a special program for the particular set of data involved since
the combination of records collected from disparate sources has been
neither simple, direct nor painless. Ultimately, we feel that the
previous programs will be combined into one general purpose program
(possibly excepting the function of selecting matching files).
Whether or not we combine the programs depends on the saving in through-
put time, which is determined by the trade-off between input-output
time (including tape rewind) and internal computing time.

Appendix A

KEYPUNCH FORMATS AND LIST OF FORMS AVAILABLE FOR RAND/TAC SYSTEM

For the reader's convenience, this appendix lists the forms in-
cluded in Appendixes B through G of Volume I for the RAND/TAC system.
Also included in this appendix are the Keypunch Formats.

Operations Forms

CD form 101	Sortie Debriefing
CD form 101	Debriefing of Combat
CD form 101	Degradation Factors During Flight to and from Target
CD form 101	Degradation Factors During Combat
CD form 101	Combat Crewmembers' Comments and Recommendations
CD form 101	BDA
CD form 102	Joint Services Anti-Aircraft Fire Incident and Damage Report
CD form 103	FAC Poststrike Debriefing Checklist

Maintenance Forms

MIP form 305 test	
RR form 300 test	Maintenance Data Collection Record
RAND form 300	Maintenance Data Collection Record
RAND form 302	Sorties Flown, Scheduled or Scrambled
RAND form 303	Aircraft Status Summary
RAND form 305	Manpower Availability
RAND form 306	AGE Utilization
RAND form 307	Mission Go
RAND form 308	Deviations-Degradations
RAND form 309	General Purpose Information Record
RAND form 300	F-4C

Supply Forms

CD form 303	Record of Cannibalization
CD form 401 (Part A)	Demand Register
CD form 401 (Part B)	Demand Register
CD form 402	Receipt or Cancellation Register
CD form 403	NORS register

Personnel Forms

CD form 200	Personnel Data Worksheet
CD form 201	Personnel Information Data
CD form 202	Supervisor's Information Data
CD form 204	Aircrew Experience Record

Facilities Forms

Form F-1   Airfield Facilities Survey--Monthly
Form F-2   Airfield Operations, Safety and Weather
                                Survey--Daily
Form F-3   Motor Pool Survey--Weekly
Form F-4   Electrical Power Generation Survey--Monthly
Form F-5   POL Facilities Survey--Monthly
Form F-5   Munitions Facilities Survey--Monthly
Form F-7   Supply Facilities Survey--Monthly
Form F-8   Maintenance Facilities Survey--Weekly

Keypunch Formats

Edit Program Input

  Format A   Debrief Summary
  Format B   Form 300 (On-aircraft maintenance)
  Format C   Sortie-Scheduled and/or Flown
  Format D   Status Card
  Format E   Manpower Available
  Format F   AGE Utilization
  Format G   Mission Go
  Format H   Deviation/Degradation
  Format I   General Purpose Comment

Edit Program Output

  Format J   Debrief Summary
  Format K   On-Aircraft Maintenance
  Format L   On-Aircraft Work Delay
  Format M   Sortie Flown
  Format N   Sortie Scheduled, Not Flown
  Format P   Sortie Comment
  Format Q   Aircraft Status
  Format R   Manpower Available
  Format S   AGE Utilization
  Format T   Mission Go
  Format U   Deviation/Degradation Comment
  Format V   General Purpose Comment

Program Output Summary Cards

  Format W   24-hour Spread
  Format X   Analysis of Variance
  Format Y   RECSUM
  Format Z   Frequency Count
  Format AA   Off-Equipment (AFTO 211) Manhour

Program Control Cards

  Format C1   Lag/Delay
  Format C2   Analysis of Variance
  Format C3   Aircraft Histogram
  Format C4   Table Loading Stopper
  Format C5   Manpower Utilization Title Card

Keypunch Instructions and Formats (Continued)

Program Control Cards (Continued)

Format C6	Edit Program Gangpunch Master Card
Format C7	Display Program Date Select
Format C8	Display Program Tape Output
Format C9	Tape Input
Format C10	General Title Card
Format C11	Histogram Title Card
Format C12	Field Selector
Format C13	Compute Elapsed Time Program--Code Selector
Format C14	Frequency Count (FREQ) Field Locator Card
Format C15	Chi-Square Title Card
Format C16	Chi-Square Field
Format C17	Correlation Field Designation
Format C18	Correlation General Title Card
Format C19	Correlation Field Designation Table Stopper Card
Format C20	Correlation Independent Variable Test Control Card
Format C21	Analysis of Variance Header Card

Master Tables

Format M1	Work Center Master
Format M2	Tail Number Master
Format M3	2-Digit System Table
Format M4	Edit Program AGE Table

Clint Program Summary Records

Format R1	Aircraft
Format R2	2-Digit System
Format R3	Work Center

Combat Dragon Card Form 101 Operations Cards

Format CD1	Sortie Debriefing
Format CD2	Debriefing of Combat
Format CD3	En Route Degradation Factors
Format CD4	Degradation Factors on Target
Format CD5	Flight Crew Comments and Recommendations
Format CD6	BDA
Format CD7	Battle Damage Assessment Remarks

Combat Dragon Supply Edit Output Cards

Format CD8	Demands, Receipts and Cancellations
Format CD9	Cannibalization Tape Format
Format CD10	NORS

Combat Dragon Supply Edit Input Cards

Format CD11	Demands, Receipts and Cancellations
Format CD12	Cannibalization Card Format
Format CD13	NORS

EDIT PROGRAM INPUT

DEBRIEF SUMMARY

FORMAT A

FORM 300 (ON-AIRCRAFT MAINTENANCE)

FORMAT B

SORTIE — SCHEDULED AND/OR FLOWN

FORMAT C

EDIT PROGRAM INPUT

STATUS CARD

FORMAT D

AIRCRAFT TAIL NUMBER · STATUS CODE · INTO STATUS · OUT OF STATUS · NORS WORK UNIT CODE · NORS C N CODE · JULIAN DATE (YEAR, DAY) · CARD CODE · 3

FORMAT E

AVAILABLE · CARD CODE · 5

MANPOWER AVAILABLE

FORMAT F

CARD CODE · 6

AGE UTILIZATION

EQUIP. MIN. · START TIME · STOP TIME · REMOVE TIME · HR. MIN.

EDIT PROGRAM INPUT

MISSION GO — FORMAT G

DATE		AIRCRAFT TAIL NUMBER	TIME	
DAY	MO.		HR.	MIN.

CARD CODE — 7

DEVIATION/DEGRADATION — FORMAT H

DATE		AIRCRAFT TAIL NUMBER	MISSION NUMBER	SCHED. TAKEOFF		DEVIATION CODE	WORK UNIT CODE
DAY	MO.			HR.	MIN.		

COMMENTS OR ADDITIONAL CODES

CARD CODE — 8

GENERAL PURPOSE COMMENT — FORMAT I

DATE		AIRCRAFT TAIL NUMBER	MISSION NUMBER	TIME	
DAY	MO.			HR.	MIN.

COMMENTS

CARD CODE — 9

EDIT PROGRAM OUTPUT

EDIT PROGRAM OUTPUT

EDIT PROGRAM OUTPUT

FORMAT Q

AIRCRAFT STATUS

FORMAT R

MANPOWER AVAILABLE

FORMAT S

AGE UTILIZATION

EDIT PROGRAM OUTPUT

MISSION GO

FORMAT T

MISSION GO TIME			TAIL NUMBER		SQUADRON	CARD CODE
DAY NO.	HR.	MIN.				G

DEVIATION/DEGRADATION COMMENT

FORMAT U

MIS... CODE	TIME			COMMENTS (1)	TAIL NUMBER	COMMENTS (cont.)	WORK UNIT CODE	COMMENTS (cont.)	SQUADRON	CARD CODE
	DAY NO.	HR.	MIN.							H

GENERAL PURPOSE COMMENT

FORMAT V

COMMENTS (1)	TIME			COMMENTS (cont.)	TAIL NUMBER	COMMENTS (cont.)	WORK UNIT CODE	COMMENTS (cont.)	SQUADRON	CARD CODE
	DAY NO.	HR.	MIN.							9

PROGRAM OUTPUT SUMMARY CARDS

PROGRAM OUTPUT SUMMARY CARDS

FREQUENCY COUNT (FREQ) SUMMARY OUTPUT

FORMAT Z

OFF-EQUIPMENT (AFTO 211) MANHOUR SUMMARY CARD

FORMAT AA

MASTER TABLES

FORMAT M1

WORK CENTER MASTER

FORMAT M2

TAIL NUMBER MASTER

FORMAT M3

WEIGHT SYSTEM TABLE

FORMAT M4

EDIT PROGRAM AGE TABLE

CLIN; PROGRAM SUMMARY RECORDS

AIRCRAFT — FORMAT R1

SQUADRON or TYPE / CARD CODE	TAIL NUMBER	SORTIE TOUCHDOWN TIME (YEAR / MO. DAY / HR. MIN.)	SHIFT	LOAD / CONFIGURATION	NORS/G CODE	LAG (HOURS / TENTHS)	DELAY (HOURS / TENTHS)	FIX (HOURS / TENTHS)	RECOVERY (HOURS / TENTHS)	NORS (HOURS / TENTHS)	NORM (HOURS / TENTHS)	UNITS	MANHOURS (HOURS / TENTHS)	FLY TIME (HRS. / TENTHS)	RUN IDENTIFICATION

2-DIGIT SYSTEM — FORMAT R2

SQUADRON or TYPE / CARD CODE	TAIL NUMBER	SORTIE TOUCHDOWN TIME (YEAR / MO. DAY / HR. MIN.)	SHIFT	LOAD / CONFIGURATION	NORS/G CODE	2-DIGIT SYSTEM	LAG (HOURS / TENTHS)	DELAY (HOURS / TENTHS)	FIX (HOURS / TENTHS)	RECOVERY (HOURS / TENTHS)	UNITS	MANHOURS (HOURS / TENTHS)	FLY TIME (HRS. / TENTHS)	RUN IDENTIFICATION

WORK CENTER — FORMAT R3

SQUADRON or TYPE / CARD CODE	TAIL NUMBER	SORTIE TOUCHDOWN TIME (YEAR / MO. DAY / HR. MIN.)	SHIFT	LOAD / CONFIGURATION	NORS/G CODE	WORK CENTER	LAG (HOURS / TENTHS)	DELAY (HOURS / TENTHS)	FIX (HOURS / TENTHS)	RECOVERY (HOURS / TENTHS)	UNITS	MANHOURS (HOURS / TENTHS)	FLY TIME (HRS. / TENTHS)	RUN IDENTIFICATION

PROGRAM CONTROL CARDS

LAG/DELAY CONTROL CARD

ANALYSIS OF VARIANCE CONTROL CARD

AIRCRAFT HISTOGRAM CONTROL CARD

PROGRAM CONTROL CARDS

TABLE LOADING STOPPER

FORMAT C4

MANPOWER UTILIZATION TITLE CARD

FORMAT C5

EDIT PROGRAM GANGPUNCH MASTER CARD

FORMAT C6

PROGRAM CONTROL CARDS

DISPLAY PROGRAM DATE SELECT CONTROL CARD
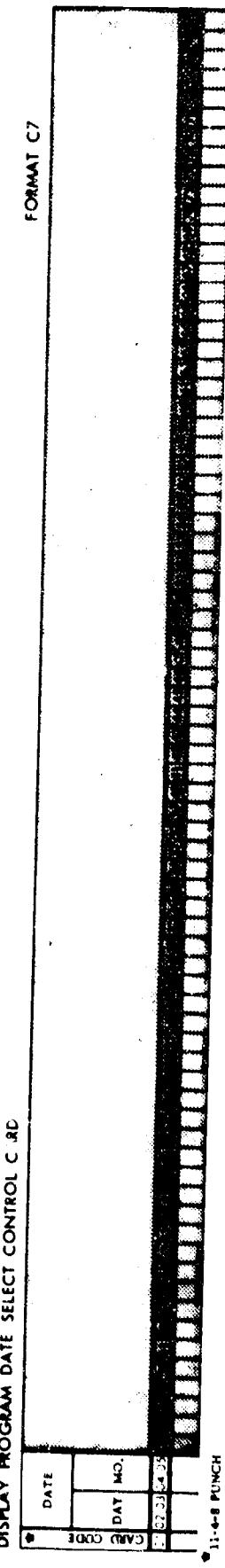
FORMAT C7

DISPLAY PROGRAM TAPE OUTPUT CONTROL CARD
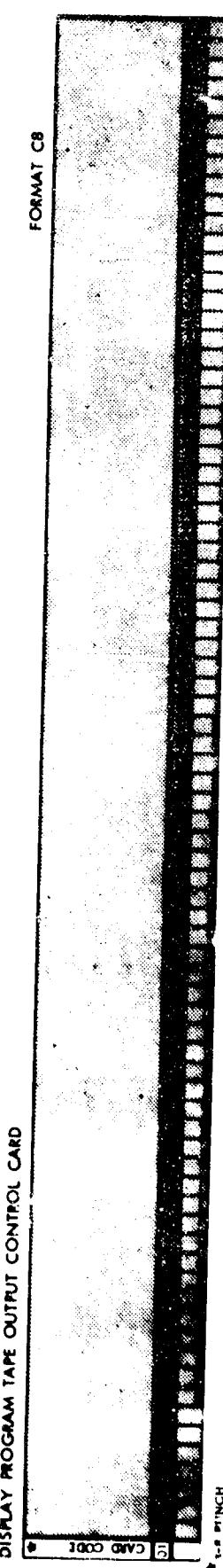
FORMAT C8

TAPE INPUT CONTROL CARD
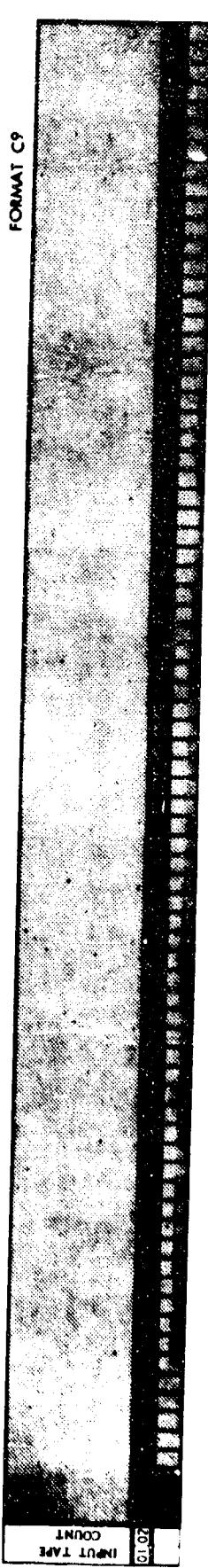
FORMAT C9

PROGRAM CONTROL CARDS

GENERAL TITLE CARD

FORMAT C10

TITLE CARD

(80-COLUMN DESCRIPTION)

HISTOGRAM TITLE CARD

FORMAT C11

TITLE CARD

(RIGHT OR LEFT HISTOGRAM)

FIELD SELECTOR CONTROL CARD

FORMAT C12

OUTPUT I.D.

CODE SELECT...

MINOR CONTROL FIELD		FIELD TO ACCUMULATE	
HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER

PROGRAM CONTROL CARDS

COMPUTE ELAPSED TIME PROGRAM - CODE SELECTOR

FORMAT C13

CODE TO SELECT
INPUT TAPE
COUNT
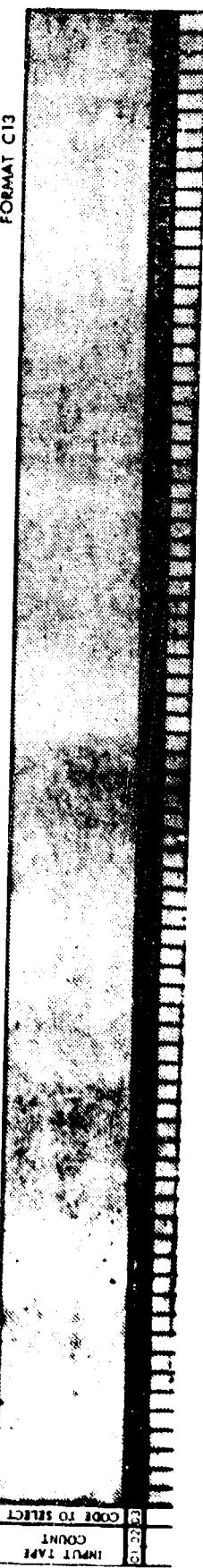
FREQUENCY COUNT (FREQ) FIELD LOCATOR CARD

FORMAT C14

LOCATION FIELD 1		LOCATION FIELD 2		LOCATION FIELD 3		TITLE	CODE IDENT
HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER		

CHI-SQUARE TITLE CARD

FORMAT C15

TITLE (1-79)	CARD CODE

*12 PUNCH

PROGRAM CONTROL CARDS

CHI-SQUARE FIELD CONTROL CARD

FORMAT C16

LOCATION OF BASE-LINE COUNT		LOCATION OF OBSERVED FRE-QUENCY COUNT		LOCATION OF CATEGORY IDENTIFICATION		LOCATION OF MAJOR CONTROL	
HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER	HIGH ORDER	LOW ORDER

INPUT TAPE COUNT

CARD CODE

* 11 PUNCH

CORRELATION FIELD DESIGNATION CONTROL CARD

FORMAT C17

FIELD POSITION

| | HIGH ORDER | LOW ORDER |

MATRIX COLUMN HEADINGS

* ANY CHARACTER

* WHOLE NUMBER DECIMAL SHIFT

CORRELATION GENERAL TITLE CARD

FORMAT C18

TITLE

PROGRAM CONTROL CARDS

FORMAT C19

CORRELATION FIELD DESIGNATION TABLE STOPPER CARD

FORMAT C20

CORRELATION INDEPENDENT VARIABLE TEST CONTROL CARD

INDEPENDENT VARIABLE TESTED

FORMAT C21

ANALYSIS OF VARIANCE HEADER CARD

TITLE

COMBAT DRAGON CARD FORM 101 OPERATIONS CARDS

COMBAT DRAGON CARD FORM 101 OPERATIONS CARDS

COMBAT DRAGON SUPPLY EDIT OUTPUT CARDS

COMBAT DRAGON SUPPLY EDIT INPUT CARDS

DEMANDS, RECEIPTS, AND CANCELLATIONS   CD Form 401, 402, June 1967

FORMAT CD11

CANNIBALIZATION CARD FORMAT

FORMAT CD12

NORS: CD Form 403, June 1967

FORMAT CD13

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10. ABSTRACT

A description of the Rand/Tactical Air Command system for the collection, processing, and analysis of data, as implemented on an IBM 1401 computer, in the management and evaluation of aircraft operations and support at base level. The second volume in the series documenting the system presents the analysis package: the recovery sequence that summarizes the operations, maintenance, and supply data by sortie and the analysis programs that process the data from the recovery sequence and the editing sequence. The discussion is directed to maintenance analysts, to familiarize them with the available programs and analysis products. Companion volumes in the series are Vol. I: Data Collecting and Editing (RM-5666-PR); Vol. III: The Analysis Design and Methods (RM-5668-PR); and Vol. IV: The System Software (RM-5669-PR).

11. KEY WORDS

Aircraft
Tactical Air Command (TAC)
Operations Analysis
Maintenance
Materials
Information systems
Information processing
Evaluation methods
Rand/TAC Information and Analysis System